MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXXXIV. FEBRUARY 8, 1923. NO. 4

ANNUAL GENERAL MEETING.

Dr. J. L. E. DREYER, PRESIDENT, in the Chair.

The Minutes of the preceding Annual General Meeting were read and confirmed.

The Report of the Auditors of the Treasurer's accounts for the year 1923 was read, and is given on p. 205.

Addresses were delivered by Sir Frank Dyson, on Meridian Astronomy (see p. 287), by Mr. Evershed, on the work of the Kodaikánal Observatory, and by Professor Turner, on the present state of the Astrographic Catalogue.

The President then delivered an address on the desirability of a new edition of Isaac Newton's works (see p. 298).

During an interval, Dr. F. W. Aston gave a short address on Isotopes.

The President having appointed the Scrutineers, the Society proceeded to the ballot for Officers and Council for the ensuing year. The names of those elected are given on p. 305

The thanks of the Meeting were given to the retiring Members of Council, and also to the Auditors of the Treasurer's accounts and to the Scrutineers of the ballot.

Captain Thomas S. Angus, late P. & O. S. S. Co., Pitreavie, Loughton, Essex;

Commander R. Griffiths Bowen, R.A.N., Naval Staff Office, Fremantle, Western Australia;

Ernest George Constable, National Physical Laboratory, Teddington, and Cobalnest, Holmesdale Road, Hampton Wick, Middlesex;

Captain Ellison Hawks, "Arcetri," Wavertree Nook Road, Liverpool;

John Laver, Mantell Street, Moonee Ponds, near Melbourne, Victoria, Australia;

Professor George Henry Livens, University College, Cardiff;

Miss Marie Hazel Losh, M.A., Ann Arbor, Michigan, U.S.A.;

Lady Lubbock, Ridlands, Limpsfield, Surrey;

Miss Ellen O'Connor, Research Student at the Imperial College of Science and Technology, S. Kensington, S.W.;

John Potter, 46 Maldon Road, Colchester;

David Ross, Peace Observatory, Kincraig, Yarra Glen, Victoria, Australia; and

Bernard P. Scattergood, M.A., M.I.E.E., F.S.A., Bennett's, Harpenden, Herts,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

John Merrill Poor, A.B., Ph.D., Professor of Astronomy, Dartmouth College, Hanover, N.H., U.S.A. (proposed by L. J. Comrie);

Bancroft Walker Sitterly, A.M., Ph.D., Assistant Professor of Astronomy, Van Vleck Observatory, Middleton, Conn., U.S.A. (proposed by L. J. Comrie);

James Stokley, jun., B.S., Central High School, Philadelphia, and 4531 Osage Avenue, Philadelphia, Pa., U.S.A. (proposed by L. J. Comrie); and

Rev. Bernard Guy Swindells, S.J., B.Sc., A.R.C.Sc., Stonyhurst College, Blackburn (proposed by A. Fowler).

Report of the Council to the Hundred and Fourth Annual General Meeting of the Society.

Progress and Present State of the Society.

	Patron	Honorary Member	Fellows: Compounders	Fellows: Annual Subscribers	Associates	Total
1922 December 31	1	1	226	606	47	881
Since elected	...	...	+4	+ 58	+3	...
Deceased	...	...	−5	− 8	−2	...
Resigned	...	...	...	− 13	...	...
Since compounded	...	...	+2	− 2	...	...
Removed from list	...	...	...	− 8	...	...
1923 December 31	1	1	227	633	48	910

(Four Associates are also Fellows, and are therefore counted twice in the above table.)

RECEIVED.

	£ s. d.	£ s. d.
Received on account of Dividends :—		
£1,250 Metropolitan 3-per-cent. Stock (Tax free) ...	37 10 0	
£2,000 Swansea Corporation 3½-per-cent. Stock (Tax free)	70 0 0	
£2,287, 6s. 9d. East Indian Railway 3-per-cent. Debenture Stock	52 14 11	
£3,500 London and North-Western Railway 3-per-cent. Debenture Stock (half-year's interest)	39 7 6	
£4,000 Midland Railway 2½-per-cent. Debenture Stock (half-year's interest)	37 10 0	
£5,125 London, Midland, and Scottish Railway 4-per-cent. Debenture Stock (half-year's interest) ...	78 3 1	
£750 London, Midland, and Scottish Railway 4-per-cent. Consolidated Preference Stock	22 13 9	
£2,400 Gas Light & Coke Co. 3-per-cent. Debenture Stock	54 9 0	
£2,000 Commercial Gas Co. 3-per-cent. Debenture Stock	46 1 3	
£3,852, 12s. 6d. War Loan Inscribed 5-per-cent. Stock (Tax free)	192 12 6	
Interest on Deposit Account (proportion)	4 12 5	
Income Tax refunded £122 14 3		
Less allotted to Trust Funds ... 8 8 4		
	114 5 11	
		750 0 4
Bequest from the late Colonel Grove-Hills		250 0 0
Sale of Publications :—		
Franklin-Adams Chart	20 0 0	
Centenary Volume (in advance)	0 15 0	
Monthly Notices, etc.	35 9 9	
Herschel Papers	30 0 0	
Reprints	75 8 0	
At Wheldon & Wesley's	194 1 9	
Herschel Papers: half share, received from Royal Society	1 0 0	
Sale of Waste Paper	1 16 9	
		358 11 3
Miscellaneous Receipts :—		
Postages, etc., repaid	8 13 0	
Sales of Photographs	56 15 0	
London Mathematical Society, for use of Rooms, etc.	30 0 0	
Received for rent and use of Telephone	0 10 2	
Received from Assistant Secretary for Pension premium	11 5 0	
Excess on certain Money Orders	0 4 0	
		107 7 2
		1465 18
Trust Fund Dividends :—		
£1,212, 13s. 3d. East Indian Railway 3-per-cent. Debenture Stock	27 19 4	
Income Tax on ditto, refunded	8 8 4	
£542, 18s. 2d. India 3½-per-cent. Stock (Tax free) ...	19 0 0	
£946, 6s. 11d. 5-per-cent. War Stock, 1929/47 (half-year's interest)	23 13 2	
		79 0 10
Special Fund :—		
Donations in 1923	63 6 0	
Interest on National War Bonds	37 10 0	
Interest on Deposit Account (proportion)	6 16 0	
		107 12 0
Received on account of Subscriptions :—		
Annual Contributions for 1923	1004 17 0	
,, ,, ,, 1924, paid in advance ...	14 14 0	
Admission Fees (including 15 due in 1922)	144 18 0	
First Contributions (including 15 due in 1922) ...	91 7 0	
Arrears paid off, 1920–22	145 19 0	
		1401 15 0
Compositions		162 15 0
Bequest from the late Mrs Harry Watson		958 17 0
Balances, 1923 January 1 :—		
Cheques outstanding, 1923 Jan. 1	9 5 0	
In hand of Assistant Secretary on Petty Cash Account	3 17 0	
,, ,, ,, on Library Account	26 15 9	
At Bankers', on Current Account (including Trust Fund Balances, £111, 9s. 9d.)	257 3 1	
At Bankers', on Deposit Account (including Special Fund, £1402, 12s. 4d.)	1650 0 0	
		1947 0 10
		£6122 19 5

Examined and found correct.

(Signed) R. T. Cullen.
W. M. H. Greaves.

Astronomical Society, from 1923 *January* 1 *to December* 31.

PAID.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	199	8	11			
Clerk: Salary	84	10	0			
Extra clerical assistance, January–April	37	10	0			
Assistant Secretary for work for London Mathematical Society in 1922	10	0	0			
Porter and wife: Wages	156	8	6			
				487	17	5
House Duty	2	12	6			
Insurance	15	9	2			
Telephone	10	13	5			
Registration of Telegraphic Address	2	0	0			
				30	15	1
Postage, etc. (including postage of *Monthly Notices*) ...				119	17	0
Printing, etc.:—						
Monthly Notices, 11 numbers £827 5 6						
Memoirs, Vol. 62, part 4 ... ... 45 18 9						
Geophysical Supplements, Nos. 2 and 3 99 2 11						
Herschel Papers 39 10 0						
List of Fellows and Miscellaneous ... 162 17 7						
Reprints 74 3 3						
£1248 18 0						
Less discount ... 26 0 7						
	1222	17	5			
Photo-engraving	77	16	5			
				1300	13	10
Reproduction of Photographs for sale				81	10	9
Library:—						
Binding, etc.	123	9	6			
Equipment	10	6	0			
Purchase of books from cash balance, as per contra ...	26	15	9			
				160	11	3
Stationery and Office Expenses				26	13	2
Coal, Gas, Electric Light				82	8	10
House Cleaning, Decorating, Furniture, Fittings, and Repairs				422	8	5
Book-case for Grove-Hills Collection				125	0	0
Three Gold Medals				31	17	6
Subscription to International Telegrams Bureau				1	9	7
Miscellaneous Expenses				55	9	5
Pension Premium for Assistant Secretary				33	15	0
Expenses of R.A.S. Meetings	18	12	9			
Expenses of Geophysical Discussions	8	12	6			
Expenses of L.M.S. Meetings	7	10	8			
				34	15	11
Bank Charges and Cheque-Book	1	2	7			
Deficit on certain Money Orders	0	0	9			
				1	3	4
				2996	6	6
Purchase of two £500 National War Bonds, 1927, 1929 (Special Fund)	1072	16	5			
Purchase of £946, 6s. 11d. 5-per-cent. War Stock (Mrs Watson's Bequest)	958	17	0			
				2031	13	5
Expenditure on Trust Accounts:—						
Lee and Janson Fund	32	4	2			
Harry Watson Funds	22	1	10			
Turnor and Horrocks Fund	17	1	0			
Hannah Jackson Fund	50	4	2			
				121	11	2
Cheque outstanding, 1923 Jan. 1				13	6	8
Balances, 1923 December 31:—						
Cheques not yet credited	2	0	6			
In hand of Assistant Secretary on Petty Cash Account	12	13	2			
At Bankers', on Current Account, as per Pass Book	485	5	7			
At Bankers', on Deposit Account (including £237, 7s. 11d. Special Fund)	391	3	0			
At Bankers', on "C" Account (Trust Funds) ...	68	19	5			
				960	1	8

REVENUE

		£	s.	d.	£	s.	d.
By Subscriptions—							
478½	Annual Contributions for 1923 (including 18 from Fellows elected 1923 January) ...	1004	17	0			
5	ditto, paid in advance in 1922, and now matured	10	10	0			
124½	ditto, outstanding	261	9	0			
8	Contributions due, but unpaid, in respect of Fellows resigned or names removed, and written off per contra	16	16	0			
616					1293	12	0
,, 22	First Contributions, 1923, at 2 guineas	46	4	0			
28	ditto, at 1 guinea...	29	8	0			
8	ditto, outstanding	8	8	0			
58					84	0	0
,, 54	Admission Fees, 1923	113	8	0			
8	ditto, outstanding	16	16	0			
62					130	4	0
,, 4	Composition Fees	126	0	0			
1	since Compounded	31	10	0			
1	Reduced Composition Fee	5	5	0			
6					162	15	0
,, Sundry Debtors, 1923					49	19	3
,, Dividends, Col. Grove-Hills' Bequest, Sales of Publications, and Miscellaneous Receipts, as per Cash Account					1465	18	9
,, Income Tax deducted, but outstanding, 1923 April–December					68	2	5
,, Excess of Expenditure over Income, 1923					322	12	1
					£3577	3	6

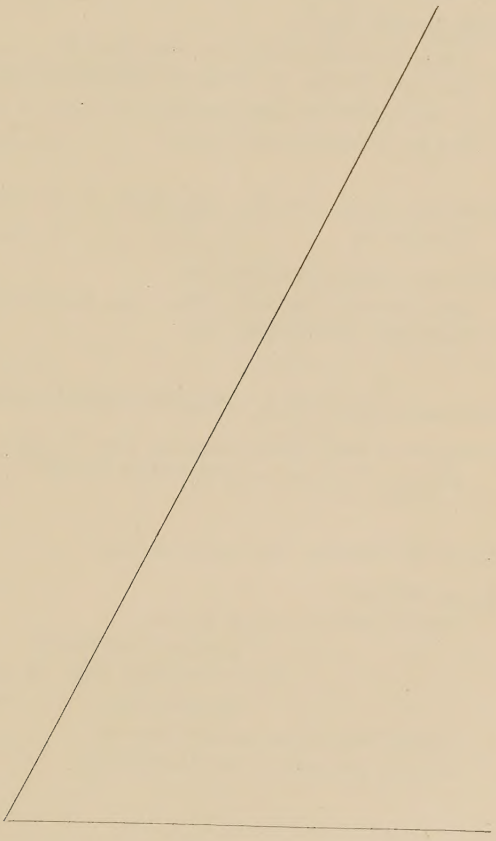
Examined and found correct.

(Signed) R. T. CULLEN.
W. M. H. GREAVES.

1924, *January* 24.

ACCOUNT, 1923.

	£	s.	d.	£	s.	d.
To General Expenditure as per Cash Account				2996	6	6
,, Reserve for Accounts due but not presented				500	0	0
,, 27 Annual Contributions in Arrear and written off ...	56	14	0			
,, 2 Admission Fees 1922 written off	4	4	0			
,, 2 First Contributions 1922 written off	3	3	0			
,, 8 Annual Contributions 1923 written off as per contra	16	16	0			
				80	17	0



£3577 3 6

BALANCE SHEET,

ASSETS.

	£ s. d.	£ s. d.
Sundry Debtors for Subscriptions in Arrear—		
16 for 1921	33 12 0	
48 for 1922	100 16 0	
124½ for 1923	261 9 0	
8 First Contributions for 1923 Nov., Dec.	8 8 0	
8 Admission Fees for 1923	16 16 0	
		421 1 0
Sundry Debtors, 1922	... ...	1 13 0
Sundry Debtors, 1923—		
Due for Publications sold (including Reprints) ...	10 2 4	
Due from Wheldon & Wesley for Publications sold during the last quarter of 1923	39 4 11	
Due for Photographs and Postages	0 12 0	
		49 19 3
Investments as per list on p. 204, valued as on 1922 December 29		14,986 0 0
Investment of Special Fund at cost—		
£500 National War Bond 1927	541 11 2	
£500 National War Bond 1929	531 5 3	
		1,072 16 5
Investments of Trust Funds, valued as on 1922 December 29	991 0 0	
Investment of Harry Watson Memorial Fund at cost—		
£946, 6s. 11d. 5-per-cent. War Stock 1929–47 ...	958 17 0	
		1,949 17 0
Income Tax deducted, 1923 April–December		68 2 5
Sundry Balances—		
Cash at Bank on Current Account	485 5 7	
,, ,, "C" Account (Trust Funds) ...	68 19 5	
,, ,, Deposit (including £237, 7s. 11d. Special Fund)...	391 3 0	
Cash in hand of Assistant-Secretary	12 13 2	
Cheques not credited, 1923 December 31	2 0 6	
		960 1 8
		£19,509 10 9

Astronomical and other Manuscripts, Books, Prints, Photographs, and Instruments.

Furniture, etc.

Stock of Publications and Photographs.

Two Gold Medals.

SCANNED

1923 *December* 31.

LIABILITIES.

	£ s. d.	£ s. d.
2 Subscriptions 1924–25, paid in 1922	4 4 0	
7 Subscriptions 1924, paid in 1923	14 14 0	
		18 18 0
Reserve for Accounts due but not presented		500 0 0
Cash Balances (Income) due to Trust Funds—		
Hannah Jackson Fund	34 6 3	
Lee and Janson Fund	14 1 10	
Harry Watson Memorial Fund	20 11 4	
		68 19 5
Guarantee to *Journal of Scientific Instruments*		10 0 0
Subscriptions to Centenary Volume, paid in advance 1922–23		26 11 0
Trust Funds (Capital), as per contra		1,949 17 0
Special Fund—		
As at 1922 Dec. 31 ... ...£1,402 12 4		
Donations and Interest, 1923 ... ... 107 12 0		
	1,510 4 4	
Less—Amount transferred to General Fund ...	200 0 0	
		1,310 4 4
General Fund—As at 1922 Dec. 31	15,747 13 1	
Add—Amount transferred from Special Fund ...	200 0 0	
	15,947 13 1	
Less—Excess of Expenditure over Revenue, 1923	322 12 1	
		15,625 1 0
		£19,509 10 9

227 Compounders.

Examined and found correct.

(Signed) R. T. Cullen.
W. M. H. Greaves.

1924 *January* 24.

INVESTMENTS, GENERAL FUND

AS AT 1923 DECEMBER 31.

£1250 Metropolitan 3-per-cent. Stock.

£2000 Swansea Corporation 3½-per-cent. Stock.

£2287, 6s. 9d. East Indian Railway 3-per-cent. Debenture Stock.

£5125 London, Midland, and Scottish Railway 4-per-cent. Debenture Stock.

£750 London, Midland, and Scottish Railway 4-per-cent. Consolidated Preference Stock.

£2400 Gas Light and Coke Co. 3-per-cent. Debenture Stock.

£2000 Commercial Gas Co. 3-per-cent. Debenture Stock.

£3852, 12s. 6d. War Loan 5-per-cent. Inscribed Stock.

Report of the Auditors.

We have examined the Treasurer's account of receipts and expenditure for the calendar year 1923, also the Revenue Account and Balance Sheet for that year, and have certified these accounts to be correct.

The balance in hand on 1923 December 31 amounted to £960, 1*s.* 8*d.* This figure includes £68, 19*s.* 5*d.* Trust Funds and £237, 7*s.* 11*d.* Special Fund.

The Balance Sheet shows that on 1923 December 31 the amount of the General Fund was £15,625, 1*s.*

The Revenue Account and Balance Sheet are new features and should prove of value.

The Revenue Account shows that the income for the year amounts to £3254, 11*s.* 5*d.*, and the expenditure to £3577, 3*s.* 6*d.*, there being thus an excess of expenditure over income of £322, 12*s.* 1*d.* This excess is largely due to extraordinary expenditure on furniture, house-cleaning, decorating, fittings, and repairs during the year, amounting to £422, 8*s.* 5d.

By Mrs. Watson's bequest of a further sum of £958, 17*s.* the funded property of the Society has been increased by the purchase of £946, 6*s.* 11*d.* 5 per cent. War Stock 1929–47.

The Grove-Hills Special Fund at the beginning of the year amounted to £1402, 12*s.* 4*d.* During the year further donations and interest increased the fund by £107, 12*s.* A sum of £200, however, was transferred to the General Fund, leaving the total on 1923 December 31 at £1310, 4*s.* 4*d.* Of this sum £1000 National War Bonds were purchased at a cost of £1072, 16*s.* 5*d.*, leaving a balance on deposit of £237, 7*s.* 11*d.*

The books, instruments, and other effects appear to be in a satisfactory condition. There are still six books missing as reported a year ago. Mention must be made of the rearrangement of the library during the year. This has been carried out by the Assistant Secretary, and represents in our opinion a most valuable increase to the utility of the library. Another feature is the progress made with the binding of recent issues.

The Railways Act of 1921 is responsible for another alteration in the list of investments, £3500 London and North Western Railway 3-per-cent. Debenture Stock, and £4000 Midland Railway 2½-per-cent. Debenture Stock having been amalgamated into £5125 London, Midland, and Scottish Railway 4-per-cent. Debenture Stock. This change brings about no alteration in income.

A list has been laid on the table of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

The certificates of railway and other stocks have been examined, and the stocks inscribed at the Bank of England verified.

The Balance Sheet states that there are 124½ subscriptions in arrear for 1923, amounting to £261, 9*s.* We beg to point out that this is not correct, as Fellows are not in arrear if payment is made before February 8

following the end of the previous calendar year, December 31. To remove this anomaly, and further, to simplify the accounts, we suggest that subscriptions should become due on January 1 of each year.

Finally, we are indebted to the Assistant Secretary for the facilities that have been placed at our disposal during the Audit.

(Signed) R. T. Cullen.
W. M. H. Greaves.

1924 *February* 6.

Gifts to the General Funds of the Society.

The John Lee Gift: In 1836 John Lee, Esq., LL.D., gave the Advowson of the living of Hartwell; in 1844 he gave the Advowson of the living of Stone, Bucks. In 1879 these Advowsons were repurchased by his heir, Edward Lee, Esq., for £700.

The Lawson Bequest (1856): Henry Lawson, Esq., bequeathed to the Society the sum of £200, free of legacy duty.

The Carrington Bequest (1876): R. C. Carrington, Esq., F.R.S., bequeathed to the Society £2,000 Consols.

The Lambert Bequest (1877): C. J. Lambert, Esq., presented to the Society the sum of £500, free of legacy duty, being part of a sum of money bequeathed by his father, Charles Lambert, Esq., for scientific purposes.

The Knott Gift (1899): Mrs. George Knott presented to the Society the sum of £250, to defray the cost of printing *Memoirs*, vol. lii., containing the late Mr. Knott's Observations of Variable Stars.

The Peek Bequest (1904): Sir C. E. Peek bequeathed to the Society the sum of £200, as a contribution towards the expense of printing the Rousdon Variable Star Observations (*Memoirs*, vol. lv., part 1).

The McClean Bequest (1905): Frank McClean, Esq., LL.D., F.R.S., bequeathed to the Society the sum of £2,000, free of legacy duty.

The Farrar Bequest (1906): The Rev. A. S. Farrar, D.D., bequeathed to the Society the sum of £100, free of legacy duty.

The Brook Gift (1907): C. L. Brook, Esq., gave one-third of the cost of printing Pogson's Variable Star Observations (*Memoirs*, vol. lviii.).

The Gill Bequest (1914): Sir David Gill, K.C.B., F.R.S., bequeathed to the Society the sum of £250, in aid of Astronomical Research, in grateful remembrance of a like sum paid out of the funds of the Society in aid of his expedition to Ascension in the year 1877. In accordance with his wishes this bequest was expended to defray part of the cost of publishing vol. lxiii. of the *Memoirs*, containing the Theory of the Four Great Satellites of Jupiter.

The Parsons Gift (1922): The Hon. Sir Charles Parsons, K.C.B., F.R.S., gave to the Society £2,500 War Stock (1929–47), in memory of his father, the 3rd Earl of Rosse, who made the 6-foot Reflector, and who died 1867 October 31.

The Grove-Hills Bequest (1922): Colonel E. H. Grove-Hills, C.M.G., F.R.S., bequeathed to the Society, free of legacy duty, his collection of early Astronomical and Mathematical books up to the year 1700, together with a sum of £250 to cover the expenses incurred by the Society in connection with the books.

The Grove-Hills Special Fund: As already reported to the Society, the late Treasurer collected by his private efforts, with the approval of the Council, a Special Fund to meet the immediate financial difficulties of the Society. He aimed at securing £1,800, and up to the present the Fund has reached the total of £1,510, 4*s.* 4*d.*, of which £200 has been transferred during 1923 to the General Fund to meet current expenditure. The Council are hopeful that the Fund will reach the figure originally aimed at, and they will be able, during the interval, while the Fund is available to meet present expenditure, to frame a sound financial policy for the future.

	£	*s.*	*d.*		£	*s.*	*d.*
1923 Jan. 1. Balance of Fund	1402	12	4	1923. Purchase of two National War Bonds	1072	16	5
1923. Dividends and Donations	107	12	0	Transfer to General Fund	200	0	0
				1923 Dec. 31. Balance (included in £391, 3*s.* 0*d.* at Bankers on Deposit Account)	237	7	11
	£1510	4	4		£1510	4	4

The following is the list of donors to this Fund in 1923:—

T. Allison.
J. L. E. Dreyer.
W. Hall.
R Ll. Jones.
E. H. F. Lawrence.
Sir W. Schooling.
M. C. Sharp.
E. W. White.

Trust Funds.

The Lee and Janson Fund: In 1834 John Lee, Esq., LL.D., gave £100, and in 1876 T. C. Janson, Esq., bequeathed £200, the interest to be given to the widow or orphan of a deceased Fellow. These amounts now stand in £334, 10*s.* 9*d.* East Indian Railway 3-per-cent. Debenture Stock.

	£	*s.*	*d.*		£	*s.*	*d.*
1923 Jan. 1. Balance of Fund	36	5	4	1923. Grants from Fund ...	32	0	0
1923. Dividends, East Indian Railway ...	10	0	8	Cheques	0	4	2
				1923 Dec. 31. Balance of Fund	14	1	10
	£46	6	0		£46	6	0

The Turnor Fund and the Horrocks Memorial Fund: In 1853 the Rev. Charles Turnor, M.A., bequeathed a sum of £500, which now stands in £464, 18*s.* East Indian Railway 3-per-cent. Debenture Stock. In 1876 the Society received a sum of £38, 15*s.*, the unexpended balance of a fund collected for the purpose of erecting a memorial in Westminster Abbey to Jeremiah Horrocks: to this the Society added the sum of £55, 15*s.*, and the whole now stands in £103, 6*s.* East Indian Railway 3-per-cent. Debenture Stock. The interest on these funds is to be used in the purchase of books for the Library.

		£	*s.*	*d.*			£	*s.*	*d.*
1923.	Dividends, East Indian Railway ...	17	1	0	1923.	Purchase of Books ...	16	16	10
						Cheques	0	4	2
		£17	1	0			£17	1	0

The Harry Watson Funds: In 1920 Mrs. Watson presented to the Society the sum of £300 as a memorial to her late husband, Lieut.-Col. Harry James Watson, F.R.A.S., the interest on this sum to be used for the purchase of books for the Library, such books to be indicated by a special book-plate. This gift now stands invested in £542, 18*s.* 2*d.* India 3½-per-cent. stock.

In 1923 Mrs. Watson bequeathed a further sum of £958, 17*s.* 0*d.* to the Society. The Council resolved that this sum, together with the above gift of £300, should constitute a Trust Fund, to be designated *The Harry Watson Memorial Fund*, to be used for the purchase and binding of books. This Fund now stands invested in £946, 6*s.* 11*d.* 5-per-cent. War Stock 1929–47.

		£	*s.*	*d.*			£	*s.*	*d.*
1923.	Dividends, India 3½ per cent.	19	0	0	1923.	Purchase of Books ...	21	17	8
	Dividends, War Stock 5 per cent. (half-year)...	23	13	2		Cheques	0	4	2
					1923 Dec. 31.	Balance of Fund	20	11	4
		£42	13	2			£42	13	2

The Hannah Jackson (née Gwilt) Fund: In 1861 Mrs. Hannah Jackson (*née* Gwilt) gave £300 Consols, which now stands in £309, 18*s.* 6*d.* East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in medals or other awards in accordance with the terms of the Trust.

		£	*s.*	*d.*			£	*s.*	*d.*
1923 Jan. 1.	Balance of Fund	75	4	5	1923.	Gifts from Fund ...	50	0	0
1923.	Dividends, East Indian Railway ...	9	6	0		Cheques	0	4	2
					1923 Dec. 31.	Balance of Fund	34	6	3
		£84	10	5			£84	10	5

Celestial Photographs.

The following have been added to the list of Celestial Photographs reproduced by the Society for sale to the Fellows:—

R.A.S. Ref. No.

319. Meteor and Star Trails, 1922 Nov. 16, W. Lockyer.
320. Franklin-Adams Astro-Camera, T. Cooke & Sons.
321. Hydrogen Flocculi Hα, Mount Wilson Observatory.
322. Hydrogen Flocculi Hα (4 exposures), Mount Wilson Observatory.
323. Solar Corona, 1922 Sept. 21, Wallal. Lick Obs. Exp.
324. Solar Corona, 1922 Sept. 21, Wallal. Lick Obs. Exp.
325. Jupiter, 1915 Oct. 19, Lowell Observatory.
326. Jupiter, 1917 Dec. 19, Lowell Observatory.
327. Saturn, 1909-1921, Lowell Observatory.
328. Total Solar Eclipse, 1911 April 28, Friendly Isles, J. H. Worthington.
329. Copernicus (Stereogram and Slide), Mount Wilson Observatory.
330. The Moon (age 9 days), Stereogram, J. H. Reynolds.
331. ω Centauri, 1903 Feb. 19, Royal Observatory, Cape.

Publications of the Society.

During the past year vol. lxxxiii. of the *Monthly Notices* has been published, also *Geophysical Supplements*, Nos. 2 and 3, and *Memoirs*, 62, Part 4.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :—

Fellows :—* Jalbhai Dorabjee Bharda.
† Joseph Brooks.
Walter William Bryant.
Charles Burckhalter.
S. Runsie Craig.
Ignazio Nicolas Dracopoli.
Alfred Henry Fison.
Sydney Samuel Hough.
Ernest W. F. Keevil.
Otto Klotz.
‡ Alfred Ernest Moore.
Arthur Alcock Rambaut.

Fellow and Associate :—Edward Emerson Barnard.
Associate :—H. G. van de Sande Bakhuyzen.

Joseph Brooks, who died at Sydney, New South Wales, 1918 May 9, was born on 1847 August 2 at Stockport, Chester, England. He was educated at St Peter's College, Adelaide, South Australia, and joined the South Australian Survey Department in 1863, his father, the late James Brooks, being at that time Deputy Surveyor-General. Soon after his appointment to the Service he was attached to an expedition led by the late Mr. Goyder, Surveyor-General, which set out for Port Darwin to carry out some necessary trigonometrical surveys there. The party was attacked by blacks, and two of its members killed.

In June 1877 he joined the Trigonometrical Survey Branch, Lands Department, Sydney, New South Wales, and on his retirement from the service in 1907 occupied the position of Surveyor—in charge of Trigonometrical Surveys. During the intervening period he fixed the longitude and latitude of about one hundred of the more important towns in New South Wales, the former being obtained by telegraphic communication with the Sydney Observatory, the instruments used being an 18-inch Altazimuth, Fauth chronograph, and Kullberg chronometers.

He was a member of a party organised by Mr. F. K. McClean, Tunbridge Wells, to observe the total eclipse of the sun at Flint Island, South Pacific Ocean, on 1908 January 3. At this eclipse he assisted Mr McClean in operating the De La Rue coronagraph, aperture $4\frac{5}{8}$ inches, focal length 8 feet.

* Died in 1921, but death not reported till 1923.
† Died in 1918, but death not reported till 1923.
‡ Died in 1922, but death not reported till 1923.

On 1910 May 8 (local time May 9), Mr. Brooks assisted the party under the leadership of Mr. F. K. McClean at the total eclipse of the sun at Port Davey, Tasmania. At this expedition the instruments used for determination of latitude, azimuth, time, and longitude were under his control, and comprised a sidereal chronometer by Kullberg, a 6-inch Troughton & Simms transit theodolite. Magnetic observations were also made. It rained continuously during the eclipse and no photographs could be obtained.

On 1911 April 29, he was a member of a party organised by Dr. W. J. S. Lockyer to observe the total eclipse of the sun at Vavau, Tonga Islands. He made the necessary observations for time, azimuth, latitude, and longitude, using a 5-inch Cooke transit theodolite for preliminary work, a portable transit theodolite by Troughton & Simms, a Fauth chronograph, and three Kullberg sidereal chronometers. He was also in charge of the 4-inch Cooke coronograph.

On 1877 December 20, he married the eldest daughter of the late Captain Kendall, whose father, the Rev. Thomas Kendall, was a pioneer Wesleyan minister. He leaves a widow, son, and two daughters.

He was elected a Fellow of the Society on 1891 January 9.

William Walter Bryant was born 1865 December 9 at Forthampton, near Tewkesbury, where his father was a schoolmaster. He was educated at St. George's School, whence he passed by scholarship to Pembroke College, Cambridge, where he graduated as twenty-first wrangler in 1887, a place which those qualified to judge believed to have been below his merits.

After a short period in the scholastic profession he was appointed in 1892 February as Second Class Assistant at Greenwich Observatory after competitive Civil Service examination.

Meridian observations with the Transit Circle were his first charge, and he took up the work with enthusiasm. His zeal and energy were such, that by force of example they were infused into his fellow-observers with such effect that the output of observations was doubled, and this without degradation in quality. He long held the record with over 200 observations, in both co-ordinates, single-handed in one night. It is a gratifying memorial to this earnest worker that the output is still maintained at this high standard.

He gave much attention to the fundamental errors of the instrument, especially the "Personal Equation" of the observer. He showed its variable character depending on the physical condition of the observer, and also its bearing on the obscure correction for "R – D," and suggested that this might be a contributory cause to the sudden change in the Greenwich declinations at the zenith.

From 1897 onwards he took part in the observations of double stars with the 28-inch refractor. Here, as with the Transit Circle, he proved a most skilful and trustworthy observer, especially with the more difficult objects.

In 1904 he was appointed Senior Assistant and given the superintendence of the Magnetic and Meteorological Department. The work of this branch is largely of a routine character, and it might seem difficult

to find much of an absorbing nature in the study of columns of figures. Nevertheless, Bryant became greatly interested in "averages" and "records." His wonderfully retentive memory enabled him to state off-hand any outstanding data in the Greenwich records as to rainfall, sunshine, temperature, and so forth. He joined the Royal Meteorological Society in 1906, in which he held in turn the office of Secretary (1916–1920) and Vice-President (1920–1921).

In addition to various contributions to the *Monthly Notices* of the R.A.S. and to the *Quarterly Journal* of the Roy. Met. Soc., his writings include a History of Astronomy and biographical studies of Galileo and Kepler. He also did a considerable amount of work in connection with the International Catalogue of Scientific Literature, being referee for the Astronomical Section.

His recreations were music, chess, and hockey. He was a skilful player on the pianoforte, a useful singer in various choirs, a clever chess player, and a keen sportsman on the hockey field, where he continued to play well on into middle life.

Owing to the use of considerable quantities of iron in the construction of the new buildings of the Royal Observatory, it became necessary to move the magnetic instruments to a site in the park some little distance from the observatory. The imminent electrification of the local railways has now rendered it necessary to move the magnetic observatory still further afield, and it was whilst engaged on a magnetic survey of a proposed site that illness seized him and, after a serious operation, terminated fatally on 1923 January 31.

He leaves a widow and eight surviving children—his second son was killed in Gallipoli, a blow he bore with Christian fortitude.

He was kindly and conscientious in all his dealings, and his untimely death was keenly felt by all his colleagues and friends.

He was elected a Fellow of the Society 1892 December 9. C. D.

Charles Burckhalter was born at Ohio on 1849 January 5. When still a young man he went to California and entered the insurance business in Oakland and San Francisco. He became so interested in astronomy that he devoted all his spare time to it. In 1885 he became a teacher of geography and astronomy with the direction of Chabot Observatory, then quite a small institution in the central part of Oakland.

Professor Burckhalter soon attracted attention as an astronomical enthusiast, and was appointed leader of an expedition organised by the Pacific Coast Amateur Photographic Association to observe the eclipse of the sun total in California in 1889. The results of this expedition are given in vol. i. of the *Publications of the Lick Observatory*. He joined the Lick Observatory Eclipse Expedition to Japan in 1896. He had charge of the expedition of the Astronomical Society of the Pacific for the eclipse in India in 1898, and he also observed the eclipse of 1900 May in the eastern United States. On one of these expeditions he succeeded in obtaining excellent photographs of coronal details by the use of a revolving occulting shutter to cut down the exposure on the brighter parts.

The results of his eclipse expeditions probably form his chief contributions to astronomical knowledge, but he will be best remembered for his untiring energy in the promotion of his beloved science. He had much to do with the formation of the Astronomical Society of the Pacific, of which he was one of the two secretaries at its foundation in 1889. As a member of the Society he maintained an active interest throughout his life, and was elected President twice—in 1895 and in 1908.

A lasting memorial to his memory exists in the new Chabot Observatory. He was too active an astronomer to be content with a small instrument, and his continuous efforts secured in 1915 a 20-inch refractor for the observatory, which was at the same time moved to a favourable site on Leona Heights, East Oakland. Under his direction the new observatory was erected; many of the details as well as all the essentials being arranged by himself. For the last year of his life he was in ill-health, but although he presented his resignation it was not accepted. The great fire in California, in September last, swept near the observatory and probably hastened his death, which took place on September 20. He has left many friends behind him amongst all classes. Thousands will recall his inspiring lectures to them as boys and girls. Amateur astronomers recognised him as one of the greatest amongst themselves, while the keenness and wholeheartedness he carried into his work as a professional astronomer made him beloved by the astronomers of the great Californian observatories.

He was elected a Fellow of the Society on 1892 February 12. J. J.

The Rev. S. Runsie Craig was born at Armagh on 1844 March 23. For thirty years he was rector of Moville, Co. Donegal. Here he erected an observatory and made observations, especially of the planet Mars. He took a keen interest in all branches of science, and was a member of several scientific societies. He retired on account of ill health in 1914, and resided afterwards at Upper Norwood, where he died on 1923 March 19.

He married twice, firstly, Anna Major, younger daughter of Thomas Major of Creggan, Co. Antrim, who died in 1901, and, secondly, Clara Mildred Latter, youngest daughter of Laurence Latter, who survives him.

He was elected a Fellow of the Society on 1890 March 14.

Ignazio Nicolas Dracopoli was born on 1887 December 6 at the Cap d'Antibes, France. He was educated at Malvern College and University College, Oxford. In the summer of 1908 he set out for Arizona, where he roamed about for several months, and then became a cowboy on the ranch of an old Frenchman, about forty miles from Tucson. He remained there until the summer of 1909 and then returned to his home in England. His experiences in Arizona had made him more anxious than ever to travel, and he immediately began to prepare for a trip to East Africa. He set out with his younger brother in the beginning of 1910 for Nairobi, where he did some big-game shooting.

With the desire to become a scientific traveller and explorer Mr.

Dracopoli joined the Royal Geographical Society and studied surveying under Mr. E. A. Reeves, the map curator of the R.G.S. He soon became proficient and started off for the Pinacate Mountains in the Sonoran desert, in Mexico. Here he made a map of the surrounding country, while his brother secured three specimens of the rather rare Sonoran mountain sheep.

In 1912 October, very soon after his return from Mexico, Mr. Dracopoli left England and again went to British East Africa. He went with the intention of exploring and mapping the country between the Lorian Swamp and the Indian Ocean, and to find out what happened to the River Vaso Nyiro after it entered the swamp. As that part of Jubaland was unknown, the natives unfriendly and dangerous, he had very great difficulty in getting permission to carry out his plan. However, he managed to do so at last, and, starting from Kismayu, on the coast, he crossed Jubaland and reached the Lorian Swamp from the east, which no white man had yet done. He suffered from severe illness and hardships of all kinds, but in spite of all difficulties he made an excellent map of the country through which he travelled, fixed the course of the Vaso Nyiro, and brought back much valuable information.

He described his journey in the Journal of the R.G.S., and was asked to give a lecture before the Society. He also published a book, *Through Jubaland to the Lorian Swamp.*

In the World Atlas, published by *The Times* in 1922, Mr. Dracopoli's map has its place. He was given the Bronze Medal of the Back Bequest, and elected a member of the U.S.A. Geographical Society.

A last expedition was made to British East Africa in 1914, and on August 5 of that year he was married. He immediately offered his services to the country of his adoption, for although of Italian descent, he had become a naturalised British subject shortly before the outbreak of the war. His health had been seriously impaired by his exploration of Jubaland, and he was unfitf or the fighting forces. He was given a post in the R.A.F., first in England and later in Egypt, where his exceptional gift of organisation had full scope. He was awarded the M.B.E. for military service.

In the spring of 1919 Mr. Dracopoli returned to England and bought a house at Bishop Stortford, and went into business in the city.

He died on 1923 January 7 of a cruel disease, the seeds of which were sown during his hard journey to the Lorian Swamp. He left two sons.

He was elected a Fellow of the Society on 1919 June 13.

Arthur Henry Fison was born at Hendon in 1857. He was the son of a Congregational minister. Immediately after taking his degree he took up lecturing on scientific subjects. For twenty years as Oxford University Extension lecturer he addressed large audiences in all parts of the country. In 1912 he was appointed Secretary to the Gilchrist Trust. In this connection he visited in the spring of each year various districts of Britain to organise local lecture arrangements, and in the autumn and winter to deliver lectures. He early became one of the

most successful lecturers of his day. Many who had the privilege of hearing him have borne witness to the pleasure he gave them. He had a wide knowledge of science and took great joy in the opportunity he had of passing on his knowledge to others. He seemed to have an instinct for getting into sympathy with his audience—often a very mixed one of professional and manual workers—and his enthusiasm always infected his hearers.

In 1906 he was appointed Lecturer in Physics to Guy's Hospital, and somewhat later to the London Hospital also. The lectures he had to give were for the most part elementary, but he kept in touch with all the latest developments of his subject. With the medical students he was as successful a teacher as he had been with the general public, and with them he was likewise a favourite. He had a commanding presence, a keen sense of humour, and an extraordinary power of lucid exposition. These characteristics, combined with a thorough knowledge of his subject, enabled him to interest the most difficult of audiences.

He occasionally gave lectures outside his ordinary courses, *e.g.* on relativity. In all things he was ever willing to give a helping hand. The manner of his death indicates the way in which he made himself useful to those with whom he came in contact. The staff of Guy's had subscribed money for a wireless installation for the illustration of a lecture by Dr. Fison, and also for the use of the hospital in other ways. While on the roof by himself fixing an aerial he fell through a skylight. He received severe injuries, including the fracture of a leg, and he died without regaining consciousness three days later, on 1923 February 4. A large gathering of students at the memorial service in the Chapel of Guy's testified to the high esteem in which he was held.

Dr. Fison's time was so largely taken up in lecturing that he had little time for independent research. The inspiration which he gave to others was, however, an important contribution to science. He was the author of two well-known books, *Recent Advances in Astronomy* (1898), and a *Text-Book of Practical Physics* (1911, rewritten 1922).

He married, in 1888, Alice, daughter of Prof. A. Williamson of University College, London, and left a son and two daughters.

He was elected a Fellow 1891 May 8. J. J.

Frank Flowers * was born at Lewisham on 1874 January 28. He went to South Africa in 1888, where he developed a great affection for science, especially on the geographical side. He became a Fellow of the Royal Geographical Society, the South African Geographical Society, and the Geological Society of South Africa. For many years he was on the Council of the South African Association for the Advancement of Science, and he was a contributor to its journal.

Previous to the war he was in the employment of the Johannesburg Municipality, but left it to take part in the German East Africa campaign as a Captain in the S.A. Pioneer Regiment, but like so many who went to German East Africa he contracted malaria and heart disease and ultimately died of these diseases on 1920 July 9, at Nakuru, in what is

* Death announced in *M.N.*, **83**, 4. Obituary Notice received in 1923.

now known as the Kenya Colony. He married Miss Dickens of Vicksburg, Orange Free State, in 1895, and leaves a widow and three children.

He was elected a Fellow of the Society on 1903 December 11.

R. I.

Sydney Samuel Hough was born at Stoke Newington on 1870 June 11, educated at Christ's Hospital, whence he gained a Foundation Scholarship at St. John's College, Cambridge; was Third Wrangler in 1892, First Smith's Prizeman, an Isaac Newton student, and a Fellow of St. John's. With his quite first-rate mathematical ability and a strong leaning to dynamical astronomy, he first turned his attention to questions evidently suggested by George Darwin: the oscillations of a rotating ellipsoidal shell containing fluid (his Smith's Prize Essay); the rotation of an elastic spheroid; the free period in the variation of latitude; periodic orbits; and the dynamical theory of the tides. To this last he made contributions esteemed the greatest advance in the subject since the days of Laplace, so that Darwin's last article in the *Encyclopædia Britannica* professes to be an abstract of Hough—no small compliment of a great master to a still young pupil.

In 1898 Finlay retired from the position of chief assistant at the Cape, and Hough was chosen to succeed. There was a remarkable contrast between him and his chief. Hough was a profound mathematician without previous experience of practical astronomy or known mechanical tastes, silent in debate, avoiding criticism and controversy, rather unenthusiastic in conversation. But the two men, Gill and Hough, made as strong a combination of talent as has ever been seen in an observatory. The Cape Observatory under Gill's direction had grown enormously: there was the 7-inch heliometer hard at work on the triangulation of south polar stars and the places of major planets and their satellites; the great Victoria telescope given by Frank McClean starting on line-of-sight velocities; the zones of the Astrographic Catalogue in full swing; and vast schemes on foot for the new reversible meridian circle and standard clock. By 1905, when the British Association voyaged to South Africa, these last schemes had been realised, and the small party of astronomers who went out a week early—including Backlund, Kapteyn, Donner, Bryan Cookson, and De Sitter—were able to see the fruits of the combination. Soon afterwards Sir David returned to England, and Hough in the zenith of his powers succeeded to the direction of the Royal Observatory with its great equipment complete, and everything in the most perfect order. Such an opportunity falls to few; but none could have made more of it than Hough did in the short time that fate allowed him. In the sixteen years of his rule he completed and published two catalogues of fundamental stars, each observed at least four times in each of the four positions of the doubly reversible meridian circle; he brought out five volumes of the *Cape Astrographic Catalogue*, and one containing the spherical co-ordinates of over 20,000 stars to the 9th magnitude, of the highest accuracy obtainable with combined photographic and meridian work. He discussed the meridian places of the inner planets and the heliometer measures of the outer; made a fine determination of the solar parallax (or rather of the aberra-

tion of light) from radial velocities; and investigated various problems in systematic proper motions and star-streaming. Then early in 1923 he was stricken with cancer, and with the usual alternations of operation and hope, of recurrence and suffering, he died on 1923 July 8 at the early age of 52, to the great loss of British Astronomy.

Hough had married in 1906 Miss Gertrude Annie Lee, a former student of Newnham, who died without children in 1918. He was elected a Fellow of the Royal Society in 1902, was President of the South African Philosophical Society in 1907, and first President of the Royal Society of South Africa. He will be reckoned among the best astronomers of his generation, and the two fundamental catalogues, built upon Gill's instrumental foundation, will be his enduring monument.

He was elected a Fellow of the Society on 1899 November 10.

Ernest William Frown Keevil was born in London on 1867 December 21. As a wholesale provision merchant most of his time was taken up with business, but he was always interested in astronomy. To satisfy his taste he erected a small observatory in his garden at Abbot's Langley, Hertfordshire.

He married on 1894 April 27 Marion Jane Willis, who, with a son and daughter, survives him. He died on 1923 May 4.

He was elected a Fellow of the Society 1921 December 9.

Dr. Otto Klotz. As might be expected, the Directors of all the British, Colonial, and Dominion Observatories are Fellows of our Society. In this Report we have to regret the loss of one of them, Dr. Klotz, the Director of the Dominion of Canada Observatory at Ottawa, who died on December 28 last in his 72nd year.

Otto Klotz was born on 1852 March 31 in the village of Preston, Ontario, then known as Upper Canada, where his father was Notary Public. He began his education in the public school of the village, and passed from there by the help of scholarships, received for merit, through schools of a higher educational grade, and eventually matriculated at the University of Toronto, where he won further pecuniary aid, and elected to follow the course embracing mathematics, astronomy, and science. More attention was given to these subjects in the University of Michigan, Ann Arbor, and he entered that institution in 1870, graduating there in 1872. After his college course he was occupied for several years in private practice as a surveyor and engineer, but having passed the examination for Dominion Topographical Surveyor, in 1879 he received an appointment under the Canadian Government, and for many years did much responsible work on the Survey under the Department of the Interior, for the most part in almost uncivilised regions in Western Canada. Among other enterprises he was called upon for help in fixing the boundary of a strip of land that was transferred by British Columbia to the Dominion when the first named entered the Confederation, and for reports in connection with the famous question of the Alaskan boundary. Such things entailed considerable astronomical observation, and Mr. Klotz was officially given the title of Astronomer to the Department. During this period he took part in work some-

what outside that of the Survey, for in 1892 he gave some help to Professor McLeod of McGill University in determining the trans-Atlantic longitude arc, Greenwich–Montreal, which was done in co-operation with two of the staff of the Royal Observatory, Greenwich, under the direction of the Astronomer Royal. In the latter part of the year 1902 the British Pacific cable joining Vancouver to Australia and New Zealand was completed, and Klotz was entrusted by the Minister of the Interior with the task of determining the first trans-Pacific longitude, which he did, with Mr. Werry as his colleague, in 1903, and so completed the longitude girdle of the earth, the closing error of circuit of the globe being one-fifteenth of a second of time. On his return from Australia after this work, Mr. Klotz was granted the honorary degree of LL.D. by the University of Toronto.

The longitude and other work of the Survey demanded a fixed observatory for practice and experimental work, and for rating of chronometers. The want had been partially met, first by a small building on private ground, and then in 1890 by the erection of a small transit house on land belonging to the Government. From this modest beginning arose the present observatory at Ottawa, and hence the Astrophysical Observatory at Victoria, British Columbia, with its giant 72-inch telescope, mainly through the efforts of Dr. King, seconded by Dr. Klotz. The observatory at Ottawa was begun in 1902 and completed for occupation in 1905, and though its equipment included the 15-inch equatoreal by Brashear and Warner and Swasey, which is still in use, it was understood that its primary purpose was to aid the work of the Survey, and that gravity, seismographic and possibly magnetic work as related to geodesy should be in the programme. Dr. King was put in supreme command with the title of Chief Astronomer, Dr. Klotz, his first assistant, was known first as Astronomer, and afterwards as Assistant Chief Astronomer, and to him was entrusted the branches of geophysical work above enumerated. Of the three he devoted himself chiefly to seismology, though earth-magnetism claimed much of his attention, and a systematic magnetic survey of Canada was inaugurated under his direction in 1907. He made Ottawa a seismological station of the first rank, whose records are welcome and valuable contributions to the earthquake information now in course of publication by the International Earthquake organisation. He himself prepared and published a volume of Seismological Tables much used in that work, and also details of a scheme for determining epicentres by a method of stereographic projection. He naturally represented Canada as delegate at the occasional meetings of the International Committee.

Dr. King died early in 1916, and there was an interregnum for the space of eighteen months. Though Dr. Klotz was Canadian-born, and undoubtedly British in his attitude towards the world war then going on, there was some popular feeling that in those troublous times one of the descent shown by his name should not be appointed to the higher office. This feeling was not, however, universal, for in the autumn of 1917 he was appointed to the Directorship, to the entire satisfaction of the staff, and since that time Dr. Klotz has fulfilled the duties of Chief Astronomer in a way that has left nothing further to be desired. He

attended the meeting of the International Astronomical Union at Rome in 1922 as Canadian delegate, and represented the Dominion at the 600th anniversary ceremonies at Padua in the same month. As he passed through London on his way home he was present at our centenary celebration, and appeared then to be scarcely in robust health, which proved to be the case, for trouble developed, so that he was compelled to give up work partially later in the year, and after intermittent periods of recovery he died, as has been said, at the end of 1923.

Dr. Klotz married early in life, his wife being the daughter of the then German Consul at Ann Arbor, and they celebrated their golden wedding a few weeks before his death. He had a breezy personality, which made him a pleasant companion and popular as a lecturer. Besides his degree of Toronto he held the honorary degree of D.Sc. from the University of Michigan and LL.D. from the University of Pittsburg, and was a member of, and had held office in, several scientific societies of America associated with his subjects of work.

He was elected a Fellow of the Society on 1904 June 10.

H. P. H.

[We are indebted to Dr. C. A. Chant, of the University of Toronto, and to Mr. Meldrum Stewart for much of the above.]

Alfred Ernest Moore was born in Liverpool on 1867 September 17, and died in Paraná, province of Entre Rios, Argentine Republic, on 1922 January 29.

In 1903 October the Argentine minister in London engaged his services to establish one of the four Regional High Schools to be created in the Argentine. In 1904 February Mr. Moore assumed the direction of the school, and at the same time was named Professor in Mathematics, Chemistry, and Natural Sciences.

In 1908 July he was appointed Chief of the Chemical Department in the Province of Corrientes, and having resigned the direction of the Regional High School, was named Professor in the Normal School in Mathematics and Natural Sciences. At the same time he became a member of the Superior Educational Board of the Province, and Professor of Natural History at the Normal School for girls.

Mr. Moore resigned all these charges in order to undertake the direction of several courses in the National College in Paraná, Entre Rios.

His time being taken up completely by his educational work, he had very little leisure to pursue his astronomical studies. Even so, he sent some communications to the Astronomical Observatory in Córdoba (Argentine).

Mr. Moore married Miss Raguel Cros on 1906 May 10, and had a happy home life with his wife and son.

His death was deeply mourned by all the Society in Paraná, and in order to perpetuate his memory as an example to students in the future, it has been decided to erect a marble bust in the entrance hall of the National College in Paraná.

He was elected a fellow of the Society on 1901 January 11.

Arthur Alcock Rambaut, the third son of the Rev. E. F. Rambaut, was born at Waterford on 1859 September 21. He was educated at the Royal School at Armagh, from whence he proceeded to Trinity College, Dublin. His University career was a brilliant one. He won a Science Scholarship in 1880, and in 1881 he took his degree as Senior Moderator and Gold Medallist in Mathematics and Mathematical Physics. After a brief interlude as Senior Science Master at his old school, the time came for him to commence the work in which he very soon won distinction, and in 1882 he was appointed assistant to Sir Robert Ball at the Dublin University Observatory at Dunsink. He remained there for fifteen years, of which ten were spent in association with Ball. In 1892 Ball was appointed Lowndean Professor at Cambridge, and Rambaut succeeded him as Andrews Professor of Astronomy and Royal Astronomer for Ireland.

Rambaut's earlier work at Dunsink was done with the Transit Circle. For eight years he observed regularly with this instrument, the results being published in parts 6–8 of the *Dunsink Observations and Researches*. These three catalogues contain in all nearly 3000 stars. This work came to an end in 1889, when Dr. Isaac Roberts presented the observatory with a 15-inch reflector. The first task with this instrument was to improve the mounting, and this having been accomplished satisfactorily, Sir Robert Ball and Rambaut commenced a photographic survey of the χ Persei cluster, the results of which were published in the *Transactions of the Royal Irish Academy*. It was at this time that Rambaut published researches on the effects of refraction and atmospheric dispersion on photographic measures.

In 1897 Rambaut left Dunsink to take up the post of Radcliffe observer at Oxford, which had become vacant by the death of Mr. Stone. This appointment brought him back to meridian work, which at that time formed the principal activity of the Radcliffe Observatory. He spent a great deal of time and labour in examining the long series of observations, begun by Hornsby in 1774, but never published, and he showed that they were valuable, but he was unsuccessful in obtaining the means for reducing and printing them. He also undertook an elaborate examination of the pivot errors of the Radcliffe instrument.

In the meantime a twin instrument consisting of a 24-inch photographic and 18-inch visual refractor was ordered by the Radcliffe trustees. This instrument was erected in 1902, and with it Rambaut devoted his chief activities for the rest of his life to two of the schemes projected by Kapteyn, viz. relative parallaxes in mass and proper motions in the selected areas. Of the latter task, which embraced 136 areas, the bulk of the results are unpublished, but vol. 53 of the *Radcliffe Observations*, which appeared shortly before his death, contains the results of the parallax work.

Opinions differ as to the value of this parallax work. It was proposed by Kapteyn at a comparatively early stage in the development of astronomical photography. The possibility of systematic errors arising from the different brightness of the stars was even then realised, although not so well as at a later date. The scheme was undertaken at a time when

our knowledge of parallaxes, derived from visual observations only, was very small, and it was capable of yielding results better in quality and more rapidly than the visual methods. However, it was only when the occulting shutter was applied, to cut down the brightness of the image of the "parallax" star to that of the comparison stars, that photography could give its best results. This new method is only applicable to one star at a time. Most astronomers will agree that Kapteyn's method for determining parallaxes in bulk was well worthy of being tried. The fact which has emerged from experience is that magnitude errors introduced into the results obtained are so large compared with the parallaxes themselves, that the comparison of images differing considerably in brightness will not yield the required accuracy. Rambaut undertook the task of giving Kapteyn's method an exhaustive trial, and, although the results obtained may not have repaid the labour so far as definite parallax results are concerned, they are not negligible. We may say that the work involved great patience and enthusiasm, and that Rambaut proved an ideal man to undertake it. Thoroughness was in this, as in other matters, a striking characteristic of Rambaut's work throughout his life.

Besides the work mentioned in brief above, Rambaut rendered good service to astronomy in many ways. In 1892 he associated himself with the late W. E. Wilson in researches on the solar radiation. His method for determining the orbit of a spectroscopic binary appeared in 1891 and was among the first in that field. In this connection he pointed out the importance of radial velocity determinations of visual binaries for the determination of accurate parallaxes.

He participated in two eclipse expeditions, the first to Vadsö in 1896 and the second to Placentia, in Spain, in 1900. He was elected a Fellow of the Royal Society in 1900.

Throughout his career Rambaut was an enthusiastic observer, and up to his final illness he took his share in the practical work of the observatory.

In 1883 Rambaut married Miss Emily Longford, who survives him with three sons. He was a man of a cheerful and kindly disposition, and many friends lament his loss. He died on 1923 October 14.

He was elected a Fellow of the Society on 1893 June 9. He served on the Council from 1901 to 1906, and from 1914 to 1918.

W. M. H. G.

Edward Emerson Barnard, the son of Reuben and Elizabeth Jane Barnard, was born at Nashville, Tennessee, U.S.A., on 1857 December 16. His father died before his birth, and the widowed mother found herself with limited means. Thus young Barnard grew up amid all the difficulties of straightened circumstances.

Mrs. Barnard was, however, a woman of taste and intellectual aspiration. She tutored her son in a manner likely most favourably to affect his character in after-life. Her encouragement and example soon made themselves apparent in his actions.

When very young he exhibited a spirit of self-reliance, energy, and capability which few lads of his age could show. In order to supple-

ment the slender income of the home he found employment with a photographer named Van Stavoren, and Barnard's work was to keep a cumbersome enlarging camera directed towards the Sun. For seventeen years he remained with the same employer, occupied in various details of photographic work. His patient servitude proved his reliability, and the character of his labours yielded him valuable instruction which was to prove of great benefit to him when he afterwards embarked on the photography of celestial objects.

At a very early age his mind was drawn to astronomy, and he became an observer before he had either the means or the knowledge to make much progress. A popular and attractively written book on astronomy by Dr. Dick fortunately came into his hands and served to intensify his regard for the science.

His first telescope had a $2\frac{1}{4}$-inch lens, and with this instrument he gratified his tastes. It was superseded in 1876 by a 5-inch telescope which enabled its possessor to revel more deeply in the wonders and beauties of the heavens. In the same year that he acquired his 5-inch glass the American Astronomical Association held its meeting at Nashville, where he met the renowned Simon Newcomb, who informed him that he could never expect to make his mark in astronomy without a mathematical training. This was disappointing to a lad who had very little schooling, and lacked both the means and the time to become proficient in mathematics. But it did not turn him from his purpose, and he continued to observe the moon, planets, double stars, and the wonderful star clouds in the Milky Way. A favourite object was the planet Jupiter, and he followed this planet with much zeal about the years 1880–1881, at which time the Great Red Spot was very prominent, while other markings of special character proved the disc to be unusually disturbed. He showed his special capacity for original work by discovering a curious dark marking in the south temperate zone of Jupiter, which afterwards became known as Barnard's Spot. However, it faded away in a few months.

He married, early in 1881, Miss Rhoda Calvert, who had come from the north of England along with her two brothers, who subsequently managed the photographic business. At this period he began to sweep the heavens for new comets, and on 1881 May 12 found a faint comet near α Pegasi, which he saw on two mornings, but it was never afterwards observed. A real success rewarded him on September 17, however, when he picked up a new comet which brought his name prominently before the astronomical world. During the ensuing ten years he shared with Mr. W. R. Brooks the great majority of cometary discoveries.

In 1883 he was appointed to a post in the Vanderbilt University Observatory and remained there four years, when he became Astronomer at the Lick Observatory, where he remained till 1895. During this period he discovered on 1892 September 9, the fifth satellite of Jupiter. Galileo first saw the four bright Moons of Jupiter in 1610 January, so that during the subsequent 282 years of telescopic work the fifth satellite had defied detection.

Herschel's 4-foot reflector, Rosse's 6-foot, and the other large instru-

ments erected by Lassell, Nasmyth, Common, and others had failed to reveal it. Perhaps it may be fairer to say that the observers, using some of these telescopes, had never seriously applied themselves to the task of seeking new Jovian satellites or, if they had, may have failed to adopt all the necessary expedients to aid their endeavours. Barnard kept the bright disc of the planet outside the field, and in the practical absence of glare he critically scanned the surrounding region. So the tiny ray of the new and diminutive satellite was just enabled to impress itself upon his sensitive and vigilant eye, and one of the most meritorious and interesting discoveries of modern times was effected.

It might have been done in England, but various causes or deficiencies operated to prevent its accomplishment, and so another great success was achieved by Alvan Clark's splendid refractors. The capacity of these magnificent instruments and the conspicuous ability of American observers have been triumphantly proved (if, indeed, proof were wanting) by Barnard's discovery, and by that of the two Moons of Mars by Asaph Hall at Washington in 1877. Barnard's own description of the discovery is as follows:—

> Friday being my night with the 36-inch telescope, after observing Mars and measuring the positions of his satellites, I began an examination of the region immediately about the planet Jupiter. At 12 o'clock as near as may be, to within a few minutes, I detected a tiny point of light closely following the planet and near the 3rd satellite, which was approaching transit. I immediately suspected it was an unknown satellite, and at once began measuring its position-angle and distance from the 3rd satellite. . . . The following night the use of the 36-inch was assigned to Professor Schaeberle, but he kindly gave it up to me, and shortly before midnight the satellite was again detected rapidly leaving the planet on the following side.

We will not attempt here to describe in detail Barnard's many successes in the field of observational astronomy. The astronomical books of to-day contain accounts of his work and descriptions of his chief successes, with many of his drawings or photos. Without allowing any one branch to monopolise his attention, he accepted any work which specially offered the prospect of new discoveries or of improving our existing knowledge.

The difficulties of any research or the labour attending it formed no deterrent to Barnard. In fact the obstacles to success and the critical nature of a research only formed encouraging incentives to attack and solve the problem whatever it was. A master-hand at observation like Barnard finds his zeal intensified when difficulties confront him, and he generally rises to the occasion and overcomes all impediments. Professor Barnard was an earnest, untiring worker. His labours in several departments of astronomy reckoned singly would have satisfied many individuals. His discoveries and observations of comets formed one extensive field of important work. His photographs of the Milky Way, comets, etc., formed another. Many important

double-star measures were made by him. His planetary work, consisting of observations of physical features of the planets, measures of their diameters, and of satellites also reached a considerable extent.

Barnard is to be reckoned as one of the greatest observers of all time, and his work may be compared with that of Tycho Brahe, J. D. Cassini, and the Herschels. Like them he combined skill and keenness in observing with a true scientific mind for discerning the things that were important.

Some of the earlier observers had fields practically unexplored before them, while Barnard had to glean the material that had been left to him after generations of keen students had already swept the skies and gathered in the main harvest. But he was enabled to employ the best telescopes the world had produced, placed in selected positions, and so these advantages, combined with his own great abilities, enabled him to accomplish the important work which stands to his name. He is not considered to be a specialist in the usual acceptation of the term. But his abilities, experience, and successful labours in several fields entitle him to be regarded as a high authority in each of them. In his later years he observed Novæ with unfaltering diligence, and watched their minute variations with that assiduity which distinguished him. Several of his later papers on this subject were contributed to the *Monthly Notices*.

It was not only the search for new objects that led to his successes: he would patiently watch well-known ones in order to trace out developments or variations likely to improve our knowledge. He was quick to detect the smallest peculiarity or feature which might give a clue to useful deductions. He often strayed from one department to another, but may be said to have left the mark of the master-hand upon nearly all that he touched. There is hardly any branch of astronomy that Barnard failed to improve or advance by the skilful application of his abilities, and of the powerful instruments he employed. He viewed objects not merely for contemplative or sentimental purposes, but scanned them with an eagle's eye and critical judgment in quest of some new fact or feature likely to enlighten us as to the nature of the object or the changes in progress.

He worked for love of the subject. Astronomical observation was his delight. His object was not only to discover new objects but also to search out new facts concerning old ones, and make our knowledge more complete and accurate as regards details. Comets were observed for position, Novæ were kept under frequent review and variations of light detected, planetary markings were watched; the 5th satellite of Jupiter he measured for position with great accuracy and frequently, till its periodic time was very exactly known. In fact he performed important work in many departments without selecting any particular one for special endeavour. Barnard gave his imaginative faculties no liberties. What he saw in the heavens he described with scrupulous fidelity. His papers were convincing to all who read them.

Barnard's work was so extensive during the forty-two years he devoted himself to telescopic work that it is impossible to detail his various items of successful work in the space at our disposal, and we must be

content briefly to summarise a few of his most important successes, in addition to those already mentioned.

1883 October 4. Independently discovered the Counterglow.

1889 August. Observed Brooks's Comet divided into four parts.

1897. Published his micrometrical determinations of the dimensions of the planets and satellites of the solar system made with 36-inch refractor.

1903 June. Discovered bright spots in Saturn's northern hemisphere.

1916 June. Discovered a small star (Mag. 10) with great proper motion.

1921 April. Rediscovered Pons-Winnecke's Comet, at a most important time, and at a return when it was expected to approach very near to the earth.

Photographed comets Swift (1892), Moorhouse (1908), Brooks (1911), in which remarkable irregularities in the tails were shown.

1889 January 1, 1900 May 28, 1901 May 18, and 1918 June 8, attended expeditions to observe total eclipses of the Sun, and on several of these occasions took valuable photographs of the corona.

He observed Novæ with great diligence, and was an independent discoverer of Nova Aquila III. on 1918 June 8. The objects included those of recent and much older date. In various years he obtained numbers of beautiful photographs of the Milky Way, star clusters, and planets. Many of these are on the eve of publication in an atlas of the Milky Way, which is expected to be issued by the Carnegie Institution this year. He has also left behind him a considerable amount of unpublished work.

Professor Barnard had a very entertaining and agreeable manner, and possessed a large circle of friends who admired him as much for his genial and engaging personality as for his high accomplishments. His ectures were well attended and much enjoyed, for they afforded intellectual treats to all those who were in a position to appreciate the best pictures of the heavens which the largest instruments and the most perfect photographic work could produce.

His discoveries brought him many honours, though the work which earned them naturally gave him even more satisfaction than the awards. He received the Lalande, Arago, and Janssen Gold Medals from the French Academy, the Gold Medal of our Society, and the Bruce Gold Medal of the Astronomical Society of the Pacific. He was also awarded several University distinctions and degrees, but possessing as he did the true scientific spirit he was not the man to seek honours or to parade them.

Professor Barnard suffered a great blow by the death of his wife in 1921 May. For forty years she had been his faithful helpmate and had shared with him all his successes. During the illness which attacked him in 1914 and for a time laid him aside, she was his devoted nurse. He never really recovered from the loss, and after a painful illness died on 1923 February 6, at 8 o'clock in the evening, aged 65 years.

He was elected a Fellow of the Society on 1888 February 13, and an Associate on 1898 December 9. W. F. D.

Hendrik Gerard van de Sande Bakhuyzen was born at the Hague on 1838 April 2. He studied first in Delft and, after taking the degree of Engineer there, went to Leiden as a student of astronomy under Kaiser. He took the degree of Doctor of Science in 1863, with a dissertation on the flexure of the meridian circle. From 1864 to 1867 he was a teacher at the High Schools at Utrecht and the Hague. In these years he wrote a text-book of mechanics which has seen four editions. In 1867 he was made a Professor at the Technical College in Delft. When Kaiser died in 1872, Bakhuyzen was appointed as his successor as Professor of Astronomy in the University and Director of the Observatory at Leiden, from which post he retired on account of the age limit in 1908. He died at his home in Leiden on 1923 January 8. In 1869 he married Geertruida van Vollenhoven, of Rotterdam, who after a long and happy union died in 1910. Their son, who is in the Netherlands Diplomatic Service, and two daughters survive him.

When Bakhuyzen came to Leiden, Kaiser, who had been connected with the old observatory since 1826, had at last, after many difficulties and disappointments, reached the fulfilment of his life's desire—the foundation of a modern observatory. The new observatory was opened in 1861, and Bakhuyzen was one of the first students who worked there under the powerful influence of Kaiser's enthusiasm. He very soon became one of Kaiser's favourite pupils, of whom the master said that "he seemed to be born to be an astronomer." When Bakhuyzen was forced by financial reasons to leave the observatory, where his labours were not remunerated, Kaiser considered this to be "a disaster to astronomy in Holland." That Kaiser was not mistaken in his judgment was amply proved during Bakhuyzen's long career as his successor.

Kaiser had destined the new observatory to the study of astronomy of precision. The meridian circle was the principal instrument. When Bakhuyzen took over the responsibility, he had to decide whether he would follow the same course or devote the labours of the observatory and his own to what was then generally called the "New Astronomy." Spectrum analysis had been put on a fixed basis by Kirchoff and Bunsen about a dozen years before. The discoveries of Secchi, Vogel, Huggins, Lockyer, and many others had in a very short time added many new results to our store of knowledge and opened vistas of undreamt-of possibilities. Nevertheless, Bakhuyzen deliberately chose the side of the old fundamental astronomy. He feared that the wealth of the newly opened mine might be exhausted within the next ten years or so, or at least that it would not continue to yield so many and important returns with comparatively so little labour as it had done during the previous ten years. History has belied this fear; but it does not follow that therefore Bakhuyzen's choice was wrong. He knew very well in which direction his gifts and vocation lay, and he followed this vocation. A truly scientific man cannot do otherwise. And the result has justified his choice. The Leiden Observatory was during the last quarter of the past century in the front rank of the institutions where fundamental astronomy was cultivated.

The successive programmes of meridian work undertaken by the observatory under Kaiser and Bakhuyzen were all rather extensive,

and required a long time for the observations and reductions. When Bakhuyzen took over the directorate, the programme in course of execution was the A.G. zones, which were commenced in 1870 and finished in 1876, with some repetitions and supplements in 1880–1882 and 1888–1898. The catalogue, which was prepared by J. H. Wilterdink, was published in 1902. After the completion of the zones the meridian instrument was sent to Repsold's to have the object glass and eye end made interchangeable, and after its return the observations of 84 polar stars, already planned by Kaiser, were taken in hand. These observations lasted from 1877 to 1885. Meanwhile a new programme had been added, viz. the observation of 303 stars in the declinations from $+6°$ to $-26°$, selected by the A.G. as reference stars for the southern zones. The programme further included the observation of zenith distances of two zones of stars, one near the zenith of the Cape, and one near the zenith of Leiden. These stars were also to be observed at the Cape Observatory, and from the comparison of the results corrections to the constant of refraction were to be derived. The observations of this programme were started in 1879 and finished in 1898. They were made by the members of the scientific staff of the observatory, E. F. van de Sande Bakhuyzen, Kapteyn, Stieltjes, Wilterdink; the supervision of the reductions were entrusted to E. F. van de Sande Bakhuyzen. The observatory never had a large staff of computers; on the other hand, the Bakhuyzens were only content with the utmost refinement and finish in all the details of the reductions and discussions. The consequence has been that these fine observations were not published in time to contribute to the construction of Auwers' Fundamental Catalogue for the zones of the A.G., for which they were intended. This is very much to be regretted, as the observations are of a very high quality. The Polar stars were published in the beginning of 1923. The sheets first printed off could thus be presented to Bakhuyzen as homage of the Leiden Observatory on the occasion of the fiftieth anniversary (1922 December 20) of the day that he took over the directorate. The probable errors of the co-ordinates are $\pm 0^s{\cdot}0040 \sec\delta$, and $\pm 0''{\cdot}058$ respectively. The southern fundamentals have not yet been published, but it appears from the discussions which have already been made that the Leiden places alone have probably about the same weight as Auwers' Fundamental Catalogue.

The principal characteristic of Bakhuyzen's work in observational astronomy is the painstaking care bestowed on the investigation of all instrumental and personal errors. The Leiden meridian circle was one of the first for which the pivot errors were investigated. The division errors of the circles were carefully determined, the flexure of the tube and the circles were a subject of constant attention; Bakhuyzen's first scientific publication, his inaugural dissertation in 1863, as well as his last, a paper in the *Annals of the Observatory* (13, part 1) in 1921, refer to this subject. Still more important are his investigations on the personal errors. This had always been a subject of careful attention in Leiden. Kaiser had already constructed an apparatus, called by him a "time-collimator," to determine the personal equation by the observation of moving artificial stars. Bakhuyzen designed a very much improved

apparatus, described in *V.J.S.*, **14**, 414 (1879), and more in detail in *Leiden Annals*, 7 (1889). Already during the zone observations (1870–1876) it had been the custom for the Leiden observers to determine their relative personal equations for bright and faint stars separately. Bessel, Struve, and Argelander had already suspected the influence of the magnitude on the personal equation. But the first proof of this influence was given by Bakhuyzen, *A.N.*, 2262, 1879 June, in a discussion of the meridian observations made at different observatories of the stars used by Gill in his determination of the solar parallax from Mars in 1877. At the same time, Bakhuyzen also investigated the effect of the brightness of a point on the time of perception of its sudden appearance and disappearance, which has an evident application to the observation of occultations (*Archives Néerl., 2me, Série* 6, p. 727 (1901), and *Leiden Annals*, **9**, 1915).

Refraction is another subject which had Bakhuyzen's attention all through his lifetime. The programme of refraction stars, to be observed at Leiden and the Cape, has already been mentioned. From these observations his brother derived a correction to the adopted value of the constant of refraction (that of the tables of Radau) of −0·002 of its amount. In 1907 Bakhuyzen published an investigation on the distribution of temperature in the atmosphere derived from observations made during balloon ascents, and derived the resulting effect on astronomical refraction. Also refraction in the meridian room, and its effect on the difference between direct and reflex observations, was studied as early as 1868 (*A.N.*, 1720). The refraction inside the tube, depending on a systematic distribution of temperature, was investigated in a note published in the *Leiden Annals* (**13**, 1) in 1921.

In 1874 Leiden Observatory came into the possession of the manuscript of Schoeter's *Areographische Beiträge*, containing his observations from 1777 to 1783. The manuscript was edited and published by Bakhuyzen in 1881. In Leiden were also preserved the observations of Huygens from 1659 to 1683, and of course those made by Kaiser in 1862 and 1864. From these, and many others, Bakhuyzen derived the period of rotation of Mars, with a probable error of about one-millionth of its amount (*Leiden Annals*, 7, 1, 1885), and discussed observed changes on the surface of the planet.

The transit of Venus of 1874 was looked forward to with great expectation throughout the astronomical world. From Holland an expedition was sent to the island of Réunion. The programme consisted of visual observations of the time of contact, heliometer measures of Venus on the Sun's disc, and photographic observations. Although Bakhuyzen did not personally join the expedition, the greater part of the preparation, and of the subsequent discussion of the results, was due to him. It was for the purpose of measuring the photographs secured by this expedition that he designed the measuring apparatus which was constructed by Repsold and which has become the prototype of all similar instruments since built for the measurement of photographic plates. As is well known, the results from the Venus expeditions in 1874 were somewhat of a disappointment, and in 1882 no official Dutch expedition was sent out.

The last quarter of the nineteenth century witnessed a great increase in international co-operation and organisation. Bakhuyzen from the beginning was one of the leading personalities in this movement. In 1863 the Astronomische Gesellschaft was founded, which from the beginning had a pronounced international character. Bakhuyzen was one of its members, and was for some years its president. In 1862 originated the International Geodetic Association, of which Bakhuyzen has been the *secrétaire perpétuel* from 1900. When the photographs made at the Cape of the comet of 1882, and the successful endeavours of the Brothers Henry at Paris to replace visual observation by photography in the continuation of Chacornac's zodiacal charts, had led to the first international conference at Paris in 1887, where the great undertaking of the Carte du Ciel was initiated, Bakhuyzen again took a prominent part in the discussions, and the *Bulletin du comité international permanent* contains many papers from his hand on various subjects. There were three proposals for the measuring of the plates: Kapteyn advocated his well-known parallactic method, used for the C.P.D.; Gill proposed the measurement of distances and position angles from the centre of the plate; Bakhuyzen was in favour of rectangular co-ordinates, to be measured with the apparatus designed by him for the plates of the Venus expedition. Gill abandoned his proposal in favour of Kapteyn's, but, as is well known, Bakhuyzen's plan was finally adopted. Whether this decision, which at the time no doubt appeared the wisest and safest, has been conducive to the good progress of the work, and whether it would not have been better to measure right ascensions and declinations directly by Kapteyn's method on all plates in a central bureau, constituted according to Gill's proposal, are questions which need not be answered on the present occasion.

A very large part of Bakhuyzen's life was devoted to geodesy. At the formation in 1879 of the Dutch National Geodetic Committee, Bakhuyzen was made a member of it, and from 1882 to the day of his death he was its president. His labours in this field commenced with the precision levelling of the Netherlands, executed under his direct supervision and completed in 1888. Three determinations of differences of longitude were executed by him personally: Leiden-Greenwich in 1880, together with his brother E. F. van de Sande Bakhuyzen; Leiden-Paris in 1883, in co-operation with General Bassot; and Leiden-Ubagsberg (one of the principal points of the Netherlands triangulation, important for the connection with the German system). The committee also studied the tides in Dutch ports. In this connection Bakhuyzen undertook a comprehensive investigation, published in 1913, on the change of the sea-level at Amsterdam and at den Helder from 1700 to about 1910, and discussed the evidence to be derived therefrom for the variation of latitude on the one hand, and for the secular motion of the soil on the other. In the triangulation of the Netherlands executed under the direction of the Geodetic Committee, Bakhuyzen naturally took a leading part. In 1913 a base was measured at Stroe, and the measuring rod used there was afterwards compared with the Dutch standard meter Nr. 27. Bakhuyzen's love for exact observations led him, although he was then 75 years of age, to take a large personal share in this work,

and he showed an endurance and perseverance in these difficult and tiresome observations of which many a younger man might well be envious.

Amongst Bakhuyzen's many other geodetic investigations we must mention in the first place his "compensation" of all European determinations of longitude, published in 1893, from which the great majority of the longitudes of European observatories as given in the national ephemerides were derived, until the accumulation of new material, and especially a new and more reliable determination of the fundamental difference Paris-Greenwich, made a revision necessary, which was carried out by Albrecht in 1904.

We have already referred to the International Geodetic Association. Bakhuyzen was a member of the Comité permanent, and its secretary from 1900. When the association was automatically dissolved, by failing to be renewed at the end of the 10-year period expiring in 1916, Bakhuyzen and Gautier took the initiative of keeping the work of the association, especially the reductions of the observations made at the international latitude stations, going, by founding the "restricted association" of neutral countries. At the meeting at Rome of the new International Geodetic and Geographical Union in 1922, most or all of the countries belonging to this restricted association joined the geodetic section of the new International Union. Bakhuyzen himself could not attend the meeting at Rome, but his labours were appreciated by all, and an official message of homage and sympathy was sent to him.

Of Bakhuyzen's further international activities we may mention his attendance at the conference of superintendents of national ephemerides held in Paris in 1896, to which he was invited as an advisory member, although not himself representing any of the ephemerides. Further, he represented the Academy of Sciences of Amsterdam at the triennial meetings of the International Association of Academies from 1904 to 1913.

Bakhuyzen's merits as a scientific man and organiser were widely acknowledged as well abroad as at home. He served on several national and international committees, and whenever extreme accuracy of observation or discussion was required, his advice was called in. He was correspondent of the Institut de France, foreign member of the Academia dei Lincei, and of the Belgian Royal Academy; further, he was commandant of the Légion d'Honneur, and he also had Russian, German, and Danish Orders. This list of honours bestowed upon him is probably not complete. He was elected a Fellow of the Royal Academy of Sciences at Amsterdam in 1872, and served as its president from 1904 to 1910. He, being elected in 1882, was at the time of his death the oldest associate of the Royal Astronomical Society.

DE S.

Proceedings of Observatories.

The following reports of the proceedings of Observatories during the past year have been received from the Directors of the several Observatories, who are alone responsible for the same.

Royal Observatory, Greenwich.
(*Director, Sir Frank Dyson, Astronomer Royal.*)

Transit-circle.—The number of transits observed during the year was 9909, including 132 of the sun and 107 of the moon. The working catalogue contains all stars between 32° and 64° declination as bright as magnitude 7·9, and some fainter stars in the sparse regions. In the two years of observation the majority of the stars have been observed at least once, but there has been the usual difficulty in getting the observations near 6^h of R.A. Steady progress has been made in the reduction of the observations of the Backlund-Hough stars made in the years' 1915–1921. All the Boss stars have now been reduced to the epoch 1925·0 by application of the Boss proper motion for the few years' interval from the actual time of observation. Proper motions are being computed for the other stars so that all the stars may be reduced to the same epoch.

Altazimuth.—Three extra-meridian observations of the moon were obtained in January and February. After this a scheme was commenced for observing transits of fundamental stars in the prime vertical. A working catalogue was prepared containing Boss stars of magnitude 5·4 or brighter between declination 11° 41′ N. and 50° 0′ N. for 1925·0. The lower limit of declination was chosen to correspond with an altitude of 15° on the prime vertical. The total number of stars is 601. The number of transits observed between June and the end of the year was 1950. The instrument is reversed weekly in its Y's, so that any residual error of collimation may be eliminated. The time is adopted from the transit-circle observations, and it is proposed to use the altazimuth observations to check the system of Boss declinations.

Cookson Floating Telescope.—The number of plates taken in 1923 was 216, a little below the average for past years. The measuring is practically up to date, and it is hoped to publish soon the values of the latitude variation for the Greenwich meridian in 1923.

Occultations.—Observations of 5 disappearances and 1 reappearance of stars occulted by the moon were obtained by one or more observers. The disappearance of Aldebaran was observed on January 27 and both phases on October 27.

Moon.—An analysis was made of the long-period inequalities in the moon's longitude, also of the parallactic inequality and terms related to

it. The Greenwich observations of the moon from 1850 to the end of 1922 (these being the limits of time for which Hansen's tables are available) have been compared with the tables corrected by the terms deduced by Dr. P. H. Cowell in a series of papers to the Society about 1905. The final residuals in longitude and latitude are being printed in the 1920 volume of Greenwich observations.

28-inch Refractor.—During the year 718 observations of 400 double stars were secured. They are distributed as follows:—

Separation.	No. of Stars.
under 0″·5	54
0″·5–1″·0	91
1″·0–2″·0	120
over 2″·0	135

The observations of stars, observed at least three times from the formation of the new working catalogue in 1920 till early in 1923, are being printed in the 1920 volume. All the Burnham stars between 0° and 60° declination and requiring observations have been placed on the catalogue for observation. This includes a large proportion of stars with very faint companions.

In 1923 January various small alterations to the instrument were carried out. The micrometer was altered so that one screw carries both wires and the other gives a relative motion to the wires. Only one micrometer head has now to be read, the other being used to take up small irregularities in the clock-work. The position circle has been redivided, and new micrometer heads graduated on vegetable ivory have been added. A new strip carrying graduations has been attached to the declination circle. This is read by a small telescope from the eye-end.

Thompson Equatorial.—The principal work has been the determination of stellar parallaxes. 1057 plates have been exposed for this programme and 1097 have been measured. The parallaxes of 50 stars have been communicated to the Society. In accordance with the scheme to determine the proper motions of parallax stars in both co-ordinates, 203 plates were measured. The proper motions determined from an interval of six or seven years have probable errors of ±0″·002 or ±0″·003.

For the determination of the effective wave-lengths of stars near the North Pole, 70 plates were exposed and 45 were measured. Also 13 plates with short exposures on standard stars were taken and measured. This work is now practically complete from the Pole to 82° declination, and includes over 2000 stars. It will be extended as opportunity offers.

No further plates have been taken with the prism crossed by a grating attached to the 30-inch reflector. A photometer for the measurement of the plates has been constructed at the Observatory, and is now nearly ready for use. It is designed for visual observation, and is of the Hartmann type with modifications.

Astrographic Equatorial.—This instrument was re-erected in 1922

December after return from the eclipse expedition to Christmas Island, and was ready for use at the beginning of the year. The principal programme undertaken with it is now the determination of photographic proper motions. Photographs with an exposure of 10^m or 12^m are taken through the glass, so that they can be measured film to film with the original astrographic plates taken about thirty years ago. As the earliest plates were for zone 65°, work has been commenced in that zone, and of the 75 plates required for it, 60 have been taken, 55 measured, and 43 completely reduced. Sixteen plates have been taken in zone 67°. All the stars given in the Astrographic Catalogue are being measured for proper motion. When the proper motion exceeds 3″ or 4″ a century, it should be obtained unless for a few stars near the corners of the plates.

Photoheliograph.—Photographs of the sun were obtained on 220 days in the year 1923. At the Cape Observatory photographs were obtained on 329 days. There are 11 days for which there are no observations at Greenwich or the Cape, but on 10 of these days photographs were obtained at Kodaikánal.

The combined series of photographs has been measured from 1921 November to 1923 June 29, and the computations completed to 1923 June 15. The copy for press for 1922 is completed, and that for 1923 is as far advanced as possible.

The approximate mean daily area (corrected for foreshortening) in millionths of the sun's visible hemisphere for the year 1923 is 55.

The progress of the cycle is shown by the following table:—

Year.	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.	1922.	1923.
Area	7	152	697	724	1537	1118	1052	618	420	252	55

Wireless Time-Signals.—Signals from Paris, Nauen, Bordeaux, and Annapolis have been received regularly, and during the winter months also from Moscow. The European signals are generally received automatically on a syphon recorder operated by means of an oscillating valve relay system. The Annapolis signals have been similarly recorded on 60 per cent. of the days up till October, after which there has been considerable interference from long-wave stations on the continent. The results of the Paris, Nauen, and Annapolis signals are being incorporated in the annual volume beginning in 1921; previous results have been communicated to the Society.

Solar Eclipse of 1922 *September* 21.—As intimated a year ago, no results were obtained from the expedition to Christmas Island on account of cloudy weather. Mr. G. F. Dodwell, Government Astronomer at Adelaide, sent his eclipse and comparison plates for testing the Einstein deflection to Greenwich for measurement. The results, confirming the predicted displacement, have been communicated to the Society in a joint paper by Mr. Dodwell and Mr. Davidson.

Printing.—The Greenwich Observations for 1918 and 1919 have been distributed. The volume for 1920 is in the binder's hands, and the printing of the volume for 1921 is well advanced.

Staff.—By the death of Mr. W. W. Bryant on 1923 January 31 the Observatory lost a very faithful and zealous worker. Mr. Witchell

was promoted Assistant and put in charge of the Magnetic and Meteorological Department. Mr. Stevens was promoted to the higher grade of Junior Assistants. Messrs. G. W. Rickett and G. F. Wells were appointed Junior Assistants on March 20 and May 23 respectively. Mr. H. S. Jones, Chief Assistant from 1913 July 1, was appointed H.M. Astronomer at the Cape Observatory, and left with the good wishes of the Greenwich staff on November 7. Mr. W. M. H. Greaves, Fellow of St. John's College, Cambridge, has been appointed to succeed him.

Royal Observatory, Edinburgh.
(*Director, Professor R. A. Sampson, F.R.S., Astronomer Royal for Scotland.*)

The work of the observatory has continued upon the same lines as last year. The clock, Riefler No. 450, for the Survey of India, after the completion of extensive tests, was dismounted and despatched to Dehra Dûn. Its place was taken by a new clock purchased for the observatory, Leroy No. 1230, a sister clock to the *directrice* of the Observatory of Paris. The escapement is a modification of an escapement of Reid of Edinburgh, by which the impulse is conveyed through small springs attached to the head of the pendulum. The three chief clocks, Riefler No. 258, Shortt, and Leroy No. 1230, are compared daily with the microchronograph. A paper embodying the conclusion with regard to their going, and that of Riefler No. 450, was communicated to the Royal Society of Edinburgh in 1924 January. The astronomical objective of these studies is to develop a reliable alternative to transit circle observations for time, valid for intervals as long as possible.

A new self-registering micrometer, hand driven, has been constructed for the Transit Circle by Messrs. Troughton & Simms, and was brought into use in the summer.

A large number of spectra of stars, down to the 3rd magnitude, have been taken with the Cooke 6-inch photo-visual lens, and reproduced with the Koch microphotometer, in extension of the studies begun last year. Accessary points connected with density of photographic images have been investigated.

A reconstruction of the mounting of the solar spectroscope has interrupted observations during the past year.

Remeasurements of magnitudes of stars in the Perth Astrographic plates have been continued. Publication of the measures, undertaken last year by the Observatory of Perth, has been interrupted by the Government of Western Australia, in the interests of economy.

A new installation for observing and recording wireless time-signals has been constructed by Messrs. Siemens Bros. & Co., and was erected in December. Subject to difficulties incident to handling new apparatus, good records have been obtained.

Royal Observatory, Cape of Good Hope.
(Director, Mr. H. Spencer Jones, H.M. Astronomer.)

The present report comprises the work done during the years 1921, 1922, and 1923.

The Observatory has suffered a severe loss by the death of Mr. Hough, who was associated with it for twenty-five years—for nine years as Chief Assistant and for sixteen years as H.M. Astronomer.

Mr. Spencer Jones was appointed H.M. Astronomer on 1923 July 30 and arrived at the Observatory on December 3.

Mr. Pead retired in 1923 August 13, after thirty-three years' service.

Mr. Tibbitts was appointed Junior Assistant, 1923 March 20.

Reversible Transit Circle.—The observations of a list of stars selected from Boss's Preliminary Catalogue, which was commenced in 1918, were continued throughout the years under review. They comprise:—

Observations of Right Ascensions:—	
Meridian transits	21,403
Determinations of collimation by collimators	326
,, ,, level	1,071
,, ,, azimuth	560
Observations of meridian marks	2,610
Observations of Zenith Distance:—	
Determinations of Zenith Distances	21,418
,, ,, runs	1,034
,, ,, nadir	937
,, ,, flexure	162

Heliometer.—Observations of the major planets at their oppositions have been continued, and the following have been secured:—

Opposition of Neptune	129 obs.	in distance	on 19 nights.
,, ,, Uranus	108 ,,	,, ,,	,, 16 ,,
,, ,, Saturn	36 ,,	,, ,,	,, 17 ,,
,, ,, ,,	36 ,,	,, position angle	,, 17 ,,
,, ,, Jupiter	92 ,,	,, distance	,, 19 ,,
,, ,, ,,	20 ,,	,, position angle	,, 15 ,,
,, ,, Mars	38 ,,	,, distance	,, 5 ,,

Victoria Telescope and Astrophysical Laboratory.—The telescope and four-prism spectrograph, with short camera, have been in use on 502 nights for the photography of stellar spectra, 936 spectra being secured mainly for radial velocity determinations.

The orbits of the following binaries have been investigated:—42 Capricorni, ι Gruis, θ^1 Crucis, 28 Doradus, α Phœnicis, ω Velorum, ρ Tucanæ, β Doradus.

The Astrographic Telescope.—With this instrument 60 plates have been obtained for the determination of standard stellar magnitudes, and 129 plates of regions in the Cape Astrographic Zones for use by Dr. Innes at Johannesburg for the determination of proper motions by the

blink method, using the original chart plates for comparison. The instrument has also been used to obtain photographs of the South Polar region, of Pallas and Juno, of Comets Reid (1921), Pons-Winnecke, Encke, Reid (1922*a*), Skjellerup (1922*b*), Skjellerup (1922*d*), d'Arrest and Doubiago-Bernard (1923*a*).

The fields of the Cape Astrographic Zones are now being rephotographed through the glass, with a view to the determination of proper motions by comparison with the plates of the original series. The average interval between the plates of the two series will be nearly thirty years. Fifteen plates for this purpose have been obtained.

Photoheliograph.—Daily photographs of the sun have been continued. In all 2060 negatives have been secured on 999 days. The negatives have been forwarded to Greenwich for measurement.

Occultations.—Forty-eight separate records of occultations of stars by the moon have been observed, viz.:—

Disappearances at dark limb . .	33
Reappearances „ „ „ . .	15

Variable Stars.—The 6-inch and 7-inch equatorials were placed at the disposal of members of the Astronomical Society of South Africa for observations of southern variable stars.

Milne-Shaw Seismograph.—Daily records have been secured without serious interruptions by means of the new instrument since 1920 Oct. 15. These records are being sent regularly to the University Observatory, Oxford, for investigation.

Wireless Time-Signals.—Numerous comparisons of the standard sidereal clocks of the Observatory with the time-signals sent from Annapolis, Nauen, Lyons, and Bordeaux were made. Assuming these stations in the mean to have sent correct Greenwich time, the longitude of the old Transit Circle of this Observatory is $1^h\ 13^m\ 54^s{\cdot}66$ E. The p.e. of a single difference of time between transmitting and receiving station is $\pm 0^s{\cdot}05$. No striking evidence of systematic fluctuations in these differential quantities has so far been noticed.

Current Reductions.—(*a*) All meridian observations up to 1923 November have been reduced to exhibit apparent places. Mean places have been formed to 1923 March 31 in Right Ascension, and to 1922 September 4 in Declination.

Ledgers of results of current meridian observations have been made to 1921 December, and star corrections examined to 1923 July 6.

Proper motions have been determined for those stars which are contained in the Second Cape Fundamental Catalogue (1912–16), and are not contained in Boss's Preliminary General Catalogue.

(*b*) Heliometer observations of major planets made between 1911 and 1921 have been reduced and the results published.

(*c*) All observations of occultations to the end of 1922 have been reduced and MS. prepared for press.

(*d*) The photographic magnitudes of C.P.D. stars brighter than 9th magnitude, which are contained in the C.A.Z., have been derived from the observed diameters and have been standardised to the Cape South

Polar Sequence. Except for revision of outstanding discrepancies the work is nearly completed.

Publications.—The following publications have been issued from the press:—

Cape Independent Day Numbers, 1923 and 1924.

Cape Meridian Observations, 1912–17.

Second Cape Fundamental Catalogue for the equinox 1900, containing the positions of 1846 stars, based on meridian observations, 1912–16.

Cape Zone Catalogue, 1900, giving the positions of 20,843 stars between 40° and 52° S., based on Carte du Ciel plates of the Cape Zone, and containing R.A. and Dec. of all stars brighter than the 9th magnitude and of all the stars used as standards.

Cape Astrographic Zones, vols. 4, 5, 6, with centres on zones $-44°$, $-45°$, $-46°$.

Annals, vol. 8, part 5.			Results of meridian observations of the Sun, Mercury, and Venus, 1912–16.
,,	,, 8,	,, 6.	Observations of major planets, 1911–21.
,,	,, 10,	,, 5.	Radial velocities of 120 southern stars.
,,	,, 10,	,, 6.	The variable orbit of the spectroscopic binary, 42 Capricorni.
,,	,, 11,	,, 4.	Discussion of a series of meridian observations made with the R.T.C. during the year 1917.
,,	,, 11,	,, 5.	Ephemerides of 99 southern circumpolar stars derived from observations, 1830–1917.

The following publications have been passed for press:—

Cape Astrographic Zones, vols. 7 and 10, with centres on zones $-47°$ and $-50°$ respectively.

Proof-sheets for vol. 8 have been passed up to 8^h R.A.

Annals, vol. 10, part 7. On the orbits of 7 spectroscopic binary stars.

Independent Day Numbers, 1925.

Miscellaneous.—Statistical investigations of the relation between the luminosities and the masses and dimensions of the stars have led to the discovery of an empirical formula connecting the effective surface temperature with the mass and density, which appears to apply to stars throughout the entire range of evolution.

A paper containing the results of these investigations will shortly be submitted to the Society.

The time-signal and meteorological observations have been maintained as usual.

Royal Observatory,
Cape of Good Hope:
1924 *January* 3.

Cambridge Observatory.
(*Director, Professor A. S. Eddington, F.R.S.*)

Work has been continued on the determination of the proper motions of faint stars by comparison with plates taken about eighteen years previously. This has occupied most of the time of the staff. Ten more

regions have been fully measured and reduced. The statistical discussion of these proper motions shows very clearly the prevalence of star-streaming among stars of magnitude 9 to 12 in substantial agreement with the star-streaming among brighter stars. There is, however, fairly consistent evidence that the proportion belonging to Stream II. is greater for faint than for bright stars. Two papers by Dr. Smart containing the results for 8 of these regions, containing altogether 1200 stars, have been communicated to the Society. There are many outstanding problems with regard to the exact constants of the streams and to deviations in the proportions, and possibly also in the velocities, in different parts of the sky; it is hoped that the accumulation of further results on these lines will help to settle some of the questions which have arisen.

With the Sheepshanks telescope 146 plates have been secured. Of these, 51 plates of 18 regions were taken "through glass" for use in the foregoing investigations; 53 plates of 29 Kapteyn areas were taken as a basis for future work.

Solar Physics Observatory, Cambridge University.
(*Director, Professor H. F. Newall, F.R.S.*)

Spectroheliograph.—Photographs of the sun's disc in K_{232} light were obtained on 102 days (previous year, 94); and photographs of the prominences at the sun's limb were obtained on 91 days (previous year, 81).

The solar activity continued to decline throughout the year, and the established occurrence of disturbances in high latitudes indicates that the minimum will probably occur in 1924.

For the year 1922 October 1–1923 September 30, the Director of the Kodaikánal Observatory has sent 311 spectroheliograms showing the sun's disc in K_{232} light.

The examination of the Kodaikánal photographs has been continued by Mr. Butler, who has specially studied the masses of bright calcium flocculi, tracing them as near as possible to their origin of outburst and extending the investigation throughout the eleven years 1912–1922 with minimum in 1913 and maximum in 1917. The compact masses which have their outburst in the visible hemisphere are usually formed suddenly as small roundish groups either as "births" in regions previously free from existing flocculi or as "growths" in the neighbourhood of existing flocculi. Within a short time they rapidly increase and become elongated with an inclination equatorward to the west in either hemisphere. The numbers of such new formations are small (1 : 4) in comparison with the number of flocculi which cross the disc from limb to limb, and are thus phenomena of considerable longevity. The mode of extinction has also been studied: it is found to be never sudden, but takes place by gradual dissipation into smaller masses which become so scattered as to be indistinguishable from the general solar réseau. An account of the investigation has been presented to the Society.

Study of Sun-spot Records and Prominences.—The study of the proper motions of sun-spots has been continued by the Director and

Mrs. Beech; and Mr. Moss has pursued his examination of the records of prominences.

Solar Rotation.—The conditions of the sky during the summer months were singularly unpropitious for securing observations for the spectrographic determination of the solar rotation. Mr. K. Sotome, Professor of Astronomy in the University of Tokyo, has assisted in the work.

Stellar Spectra.—A list of lines still unidentified in celestial spectra was compiled by Mr. Baxandall, and has been published in the *Monthly Notices* (**83**, 166). A similar list of absorption bands of unknown origin has also been prepared by him. Some such bands recorded as present in the spectra of stars of type S by Mr. P. W. Merrill at Mount Wilson Observatory were recognised by Mr. Baxandall as probably due to zirconium oxide, and Mr. Merrill has confirmed the identification by direct comparison.

The spectra of θ *Aurigæ*, α *Andromedæ* and β *Lyræ* have been further studied by Mr. Baxandall.

Since last year's report the following papers have been published by Mr. Milne: (1) The equilibrium of a rotating star (*M.N.*, **83**, 118). In this he extends Professor Eddington's theory of the internal constitution of a star to the case of stars in rotation. (2) A memoir on the escape of molecules from the atmosphere of a gaseous star (*Camb. Ph. Trs.*, **22**, 483). He introduces a new conception by determining the height of the "escape level" and the density at that level for various temperature distributions; and concludes that even in giant stars, in spite of the low values of gravity at the surface, the gravitational potential is sufficient to retain their atmospheres completely. (3) The intensities of absorption lines in stellar spectra (with Mr. R. H. Fowler) (*M.N.*, **83**, 403). Here the authors apply the results of modern spectral theory to stellar spectra, and, by an extension of Saha's theory of ionisation at high temperatures and low pressures, they calculate the temperatures of the maximum development of lines in subordinate spectral series, and find that the partial pressure of free electrons must be taken to be very small (about 10^{-4} atmosphere) in order to bring the calculated and observed temperature scales into agreement. (4) Statistical equilibrium in relation to the photoelectric effect (*Phil. Mag.*, **47**, 209, 1924). Mr. Milne has concluded that the low pressures are intimately connected with high values of the absorption coefficients concerned in the production of the absorption lines; in this paper he determines the numerical values of such absorption coefficients by connecting them (out of a study of statistical equilibrium between atoms, ions, electrons, and radiation) with the laws of probability of electron-capture.

Work on Ionising Radiations.—The results of Mr. C. T. R. Wilson's study of his stereoscopic pictures of the tracks of electrons obtained during the last three years have been published in the *Proceedings of the Royal Society* (**104**, 1 and 192).

Dunsink Observatory.
(*Acting Director, Mr. Charles Martin.*)

The time-service to Dublin has been continued as in previous years, the meridian circle, in conjunction with the Paris signals, being used to determine mean time.

Two lectures were given to teachers in the summer, and a series of lectures was delivered in Trinity College during the winter.

Students are given a day each week for instrumental instruction, and are welcome for night work.

Some calculations have been made in connection with a comparison of the Oxford and Potsdam astrographic zones.

The observatory instruments are not in good repair.

A small sum has been expended during the year in repairing the observatory buildings and walls.

Durham University Observatory.
(*Hon. Director, Mr. Harold Thomson.*)

The 6·4-inch Peek equatorial has been used throughout the year principally in the observation of 24 long-period variable stars, and over 600 observations of these stars have been obtained during the year. In addition, observations have been made by Mr. Sargent on the surfaces of the planets Mercury and Jupiter, and the occultation of B.D. -14°, 4045 by Jupiter on May 7 and of Uranus by the Moon on October 20 were observed.

Since the last report the object-glass of the Peek equatorial has been refigured by Messrs. Cooke, Troughton & Simms, Ltd., and now gives excellent results. Modifications have been made in the method of suspension of the zenith telescope in the hope of obtaining more consistent results. The weather has been unfavourable for work with this instrument, but it appears from plates already taken that the results are not yet satisfactory. Further tests are being made with this instrument.

A wireless receiving set has been installed for the reception of time-signals, and several improvements have been made which will assist in the observational work.

The usual meteorological observations have been made and communicated to the Meteorological Office, and the Cathedral clock has been regulated as hitherto.

Liverpool Observatory, Bidston. (*Mr. W. E. Plummer.*)

The arrangements for the conduct of the Observatory by a joint Board consisting of members of the Mersey Docks and Harbour Board, the staff of the Liverpool University, and a representative of the Admiralty, mentioned in the last Report, have been satisfactorily completed. The work of reorganisation under the new constitution is proceeding slowly, and the general scheme is so arranged that none

of the activities of this Observatory in the past shall be discontinued or curtailed. It is proposed that the old instruments shall be gradually replaced, as funds accrue, by others of modern design. It is hoped that the Tidal Machine now in course of construction for the Tidal Committee will be housed here and inaugurate the new departure on lines of greater utility.

Norman Lockyer Observatory, Salcombe Hill, Sidmouth.
(Director, Major W. J. S. Lockyer, M.A., Ph.D.)

The usual routine of photographing the spectra of stars with the 12-inch McClean Prismatic Camera has been continued, and numerous spectra, on a much larger scale, of special interest have also been secured with the 9-inch Kensington instrument. Successful observations have been made on 143 nights, and 800 negatives have been obtained during the year.

The work on spectroscopic parallaxes still forms an important part of the routine work of the observatory. The parallaxes of 500 stars of types Fo to M have been published in the *Memoirs* of the Society (vol. 62, part 4), and a further 500 are in course of publication. The work on B stars has been greatly assisted by some valuable new data in the form of trigonometrical and group motion parallaxes. A paper describing the final reduction curves and giving a first list of results is well in hand.

A paper has been published in the *Monthly Notices* on the spectrum of ζ Tauri—a star which has variable bright lines of Hydrogen and Helium. Work is being continued on this star, and a systematic series of photographs of other bright line stars showing various peculiarities is in progress.

All the buildings, instruments, and apparatus are in a satisfactory condition. Lieut.-Col. F. K. McClean has presented the observatory with a very fine sidereal clock by Charles Frodsham (No. 1329). A valuable temporary addition to the equipment has been made in the form of the loan of an Aldis "W.D." triplet lens of aperture 3·6 inches and focal length 20 inches, working at f 5·6. This has been mounted in a box camera and placed on the 9-inch Kensington instrument in place of a 3½-inch Dallmeyer doublet which was previously in use. It is hoped at a later date to replace the Aldis lens by a more efficient lens of larger aperture but about the same focal length.

The Director took part in the international survey of the sky organised by the Office National Météorologique de France. Photographs of the sky were taken daily in the S.W., N.E., and Zenith directions at 7 A.M., 1 P.M., and 6 P.M. from September 24 to October 1 inclusive. Some additional photographs were taken when interesting clouds were seen in other directions, the total number obtained being 81. This set was the fifth largest sent in from observers in the British Isles.

The observatory is thrown open to the public every Wednesday afternoon, and the number of visitors who attended during 1923 was

282. In addition, visitors were admitted on the nights of June 25 and 26 from 9 P.M. onwards. On the first of these nights (which was public) over 150 visitors attended, and in spite of poor weather were able to obtain glimpses of the Moon and Planets. On the second night (which was by special invitation) 98 visitors attended, but the weather was too cloudy for any observations to be made.

Mr. Rimmer's appointment as research assistant to the Director by the Advisory Council of the Department of Scientific and Industrial Research terminated on September 30 last, but the Council of the Observatory's Corporation has appointed him to act as a second assistant to the observatory for a further twelve months.

The Council of the University College of the S.W. of England, Exeter, has appointed the Director Honorary Lecturer in Astronomy at the College.

The annual general meeting of the Norman Lockyer Observatory Corporation was held on June 28.

Radcliffe Observatory, Oxford.

(*Radcliffe Observer: Dr. A. A. Rambaut, F.R.S., until October* 14.)

The observatory has sustained a severe loss in the death of its Director, Dr. A. A. Rambaut, F.R.S., which occurred, after a distressing illness of more than a year's duration, on 1923 October 14.

The three assistants and computer have continued the previously arranged programme of observations with the 24-inch photographic refractor for the determination of proper motions.

Unfavourable observing conditions have hampered the work, but by utilising every available opportunity fifty-five plates, including four imperfect ones, were secured. Twenty-one of these were on Kapteyn's Selected Areas; thirty-one on the fields of the Radcliffe Stellar Parallaxes, taken for Professor P. J. van Rhijn, for whom also two plates were taken on the Præsepe cluster. A plate has been obtained at Professor H. H. Turner's suggestion for test of systematic error, if any, depending on the driving-clock. Seventy-two plates of the parallax fields have been forwarded to Groningen for measurement, in accordance with arrangements which had been made by Dr. Rambaut with Professor van Rhijn.

With the 10-inch Barclay Equatorial two occultations of Aldebaran by the Moon, both disappearance and reappearance, have been observed.

A search for Anderson's reported Nova was made with binoculars on the evening of May 16, but without success.

In connection with the measurement and reduction of the proper motion plates in the Selected Areas, forty-six plates, *i.e.* twenty-three in duplicate, have been surveyed. The position and brightness of 10,739 stars have been recorded, and 9,776 of these accepted for final measurement for proper motion. The total number of *separate* stars contained in this first set of plates is 5,480, of which 4,296 will be measured in duplicate.

A determination has been made of progressive and periodic errors of the measuring screws.

Measures on the above-mentioned test plate have been taken and are now under discussion.

Vol. liii. of the *Radcliffe Observations*, entitled "Determinations of Stellar Parallaxes," was completed and distributed in the summer.

Part 2 of vol. liv. (*Meteorological*) has been printed, and a limited number of copies distributed in the usual manner.

At the request of the Radcliffe Trustees, Dr. Dreyer kindly consented to act as adviser from July 1, when the late Dr. Rambaut was granted a long period of sick-leave.

University Observatory, Oxford.
(*Director, Professor H. H. Turner, F.R.S.*)

Volume VII. (Zone $+58°$) of the Vatican Astrographic Catalogue is printed with the exception of the tables and auxiliary matter. The reductions for the three remaining zones, $+57°$, $+56°$, and $+55°$, were completed last year, allowing the Ledgers of residuals to be fully entered as far as R.A. $3^h\ 20^m$, and beyond this for all zones except $+56°$ and $+55°$. The examination of discordances is proceeding.

Mr. C. Martin of Dunsink has kindly computed the 1900·0 places of stars from the Leiden Ast. Ges. Catalogue in zone $+32°$, which overlaps the Oxford terminal zone $+31°$, and was assigned to Potsdam. He is proceeding with the standard co-ordinates.

The 12·2-inch Grubb visual lens, used as a guiding telescope for the Astrographic plates, was sent to Messrs. Cooke, Troughton & Simms Ltd., of York, for examination and (on their report) for refiguring. This shortened the focal length about, say, 2·5 ins., and necessitated cutting and altering the tube; the telescope is consequently not yet again in full working order.

The seismological reductions have been pressed forward in order to catch up the arrears following from the war. The results for 1918 have been printed and distributed; those for 1919 January to March are passed for press; 1919 April to June sent to the printer, and much work done on the rest of 1919. [This achievement would not have been possible without the friendly aid of Dr. Crombie of Aberdeen, who made it possible to obtain the assistance of Mr. J. S. Hughes, B.A., of New College, for fourteen months entirely by his own benefaction, and for another year (ending in 1924 September) by providing half the salary on the understanding that the other half would be forthcoming from the Board of Scientific and Industrial Research.] The cases where the relative focal depth of a shock was abnormal and could be estimated from the arrival of waves at the antipodes of the epicentre are steadily accumulating. The periodicity of 21 minutes has been investigated by means of a list of 3000 Italian earthquakes kindly lent by Dr. R. D. Oldham, F.R.S., though the final results are not yet ready. The period of 4 years was traced in a number of records and incidentally led to the discovery of a 9-year period in magnetic observations.

The Coats Observatory, Paisley.
(Convener, Mr. Donald Campbell, M.A.)

The number of visitors to the Observatory in 1923 was 603.

The Committee regret that owing to insufficiency of funds certain important instruments which require repair are out of action, particularly the equatorial, the driving clock of which is out of order. They are considering the possibility of rectifying this as soon as practicable. The transit circle is in good order, and observations of stars for checking and regulating the clocks have been made as usual.

The rainfall for September 1923 was the heaviest registered at the Observatory since it was founded in 1883, and amounted to 7·84 inches, which fell on 24 days, or 4·83 inches above the normal for 40 years.

Imperial College, South Kensington.
(Professor A. Fowler, F.R.S.)

The astronomical equipment was mainly used for the instruction of students, but occasionally also for the observation of solar prominences. Numerous spectra were under investigation in the laboratory, and substantial progress was made with the various spectra of silicon. The series at three successive stages of ionisation have now been almost completely traced, and an account of the series of Si IV. (or Si^{+++}) has been published (*Proc. Roy. Soc.*, A, **103**, 413). This investigation was undertaken in the first instance on account of the astrophysical interest of the silicon lines, and the results may be expected to have an important bearing on questions relating to the physical conditions in the atmospheres of the hotter stars, as well as upon theories of atomic structure. The series of ionised carbon (C II.), lines of which also appear in some of the stars, have similarly been traced by the production of previously unrecorded lines. A paper by Mr. W. B. Rimmer on the emission spectrum of ammonia was also published during the year (*Proc. Roy. Soc.*, A, **103**, 696). This was an extension to the visible spectrum of a previous investigation in which certain band lines of ammonia in the ultra-violet had been traced in the solar spectrum. No further solar lines, however, could be certainly assigned to ammonia. Mr. J. A. Carroll, Isaac Newton student of the University of Cambridge, successfully carried out an investigation of the absorption spectrum of thallium vapour (*Proc. Roy. Soc.*, A, **103**, 334).

It is gratifying to report that the numerous instruments which were left in Russia in 1914 have now been returned in good condition. Much inconvenience had been suffered through their long absence.

Professor Fowler was appointed a Yarrow Research Professor of the Royal Society in December. He will continue to direct the research work of the astrophysics department, but the courses of instruction to students will in future be conducted by Assistant-Professor H. Dingle.

Stonyhurst College Observatory.
(*Director, Rev. A. L. Cortie, S.J.*)

In 1923 observations of the Sun's surface were made on 249 days and include 246 drawings. Of these drawings 233 are complete and show all spots and faculæ; the remaining 13 are complete for the spots, but not for the faculæ. The mean daily disc-area of the spots (in units 1/5000 of the visible disc) was 0·37, a decline of 21 per cent. on the value for 1922. The mean daily ranges in terrestrial magnetic horizontal direction and force have also considerably fallen from their values in 1922. This marked decrease in sun-spot activity points to an approach to the minimum for the cycle.

The only spot-group of any size was that which appeared at the end of 1922 December, in latitude +6·4° and longitude 89·7°, and was last seen on 1923 January 4. Its maximum area was 13·0 units. In the whole year there were 23 spot-groups in N. latitude with a total area of 26·9 units, and 21 groups in S. latitude with a total area of 12·3 units. There were 122 spotless days, mainly in the months January to August, as against 93 spotless days in 1922, the relative and respective proportions of all days of observation being 49·6 per cent. and 36·3 per cent. The beginning of a new and overlapping sun-spot cycle was marked by the appearance of a group in S. latitude −27·2°, August 31–September 8, and of a corresponding N. latitude group +21·2°, September 7–18. Other groups in high latitudes, though of no great size, continued to appear until the end of the year.

Work on the photography of stellar spectra has been considerably hampered by the abnormal weather conditions. There has been very much cloud, and the rainfall, 63·558 inches on 262 days, constitutes a record for the 76 years of observation. Some few stellar spectra have been secured, and some progress has been made in the correlation of absolute magnitudes and spectra of stars. A study is also being made of the 27-day periodicity in magnetic disturbances.

The magnetic, meteorological, and seismological observations have been carried on as usual, and regular returns have been sent to De Bilt, to the Meteorological Office, and to the Seismological Committee. A Government Grant from the Royal Society has been expended in the purchase of a Milne-Shaw seismograph. A synchronome clock has also been acquired, which furnishes a time-scale not only to the seismograph but to the magnetographs.

The installation of electric lighting in the College has allowed of the organisation of a subsidiary power-station for the observatory. This supplies a low voltage current for lighting the magnetographs, in addition to the high voltage circuit for general lighting purposes. The dome of the 15-inch equatorial is also rotated by an electric motor.

We have to acknowledge several benefactions of books and instruments from Mr. E. T. Whitelow, F.R.A.S.

University of London, University College Observatory.
(Professor L. N. G. Filon.)

The instrumental equipment of this observatory has for many years been used exclusively for instructional purposes. In 1921 October, Mr. C. C. L. Gregory was appointed a full-time assistant in Astronomy, and an attempt was made further to utilise and improve the existing equipment so that research might be undertaken.

The $3\frac{1}{2}$-inch Draper's Company Transit Circle by Cooke was provided with new webs, movable in right ascension by a micrometer screw, and central illumination fitted. As the instrument is not reversible, a striding level was used in conjunction with a mercury bath to obtain the errors of level and collimation independently, and the effects of ground tremors on the images of the webs were removed by using a very small depth of mercury on an amalgamated copper surface.

The chronograph by Grubb, which was out of date, was redesigned, and has since worked in a satisfactory manner. It is now actuated by the Standard Clock by Cooke, which is situated in the main building of University College.

Recently the chronograph circuit has been extended by means of a double overhead wire to give seconds signals to the Brocklebank Observatory on the roof of the main building in order that occultations may be observed with the 10-inch Newtonian Reflector. A relay has also been installed to record on the chronograph the hourly Greenwich time-signals of the Standard Time Co., Ltd.

The mirrors of the 10-inch reflector were resilvered at the observatory, and the instrument was provided with a guiding telescope and camera, designed so that photographs might be taken at the principal focus; also the driving clock has been improved so that longer exposures may be undertaken.

A $4\frac{1}{2}$-inch photographic doublet by Cooke and a small prismatic camera are also attached, but an entirely new camera for the doublet is in process of construction.

The plates are measured in the usual way, except that a réseau is bound on to the plate and not impressed photographically before exposure.

The 4-inch Chadwick equatorial refractor by Cooke has been used mainly for teaching; it is provided with a bi-filar and a split-lens micrometer, also a wedge photometer.

A concave grating by Rowland has been mounted in conjunction with a speculum metal cœlostat mirror and concave mirrors, on loan from the Joint Permanent Eclipse Committee and the Royal Observatory, Greenwich, so that the ultra-violet region of the solar spectrum may be photographed in high orders. Integrated sunlight has been used, and some successful plates were taken in August last, but these have not yet been measured.

In addition to the grating instrument, a fixed spectrograph of the Littrow type with a 6-inch half prism by Hilger has been constructed. The whole region of the spectrum for which glass is transparent can be photographed with this instrument on a 6-inch plate, and it has been found to give good definition.

Much time has necessarily been spent on improving the instrumental equipment, but this is near completion, and it is hoped that results will shortly follow which will justify the time so spent.

Wolsingham Observatory.
(Rev. T. E. Espin.)

The examination of stars in the B.D. north of Decl. +60° has been continued through the year by Mr. Milburn with the 17¼-inch reflector, and south of Decl. +40° by Mr. Espin with the 24-inch reflector, and the results have been communicated to the Society.

Mr. A. M. Newbegin's Observatory, Sutton, Surrey.

Observations for solar prominences have been continued throughout the year 1923, but the climatic conditions have reduced the total number somewhat. The results are given in tabular form:—

Number of observations = 99
„ prominences = 665
Mean daily number = 6·71
„ area = 1·99 sq. minutes
„ height = 33″·93

Distribution.	Number.	Area (sq. minutes).
North	355	1·10
South	310	0·88
East	331	0·93
West	334	1·05

Metallic prominences were observed on two occasions only, and displacements of the H_α line at the limb on eight days, six of which were to the violet.

The results show the downward tendency of activity, but it is to be noted there were one or two periods of increased disturbance during the year.

A new spectroscope was delivered in September of unusual design, consisting of three prisms and a grating. This is intended for observations of sun-spots, and experiments are now in hand for purposes of adjustment.

The Rev. T. E. R. Phillips's Observatory,
Headley, near Epsom.

The usual observations of the planets and double stars have been continued. In the early months, especially in January, there were some nights of exceptionally good seeing, but conditions were less favourable later.

The eclipse of the moon on March 2 was observed mostly through a thin veil of cirro-stratus cloud. The usual reddish or coppery tone was

not seen, and no details of the lunar features could be detected within the shadow.

The occultations of Aldebaran on January 27 and October 27 were both observed under fair conditions.

In the middle of May observations of R Coronæ were begun, and later work on a number of variable stars in their fainter stages was undertaken for the variable star section of the B.A.A.

Systematic photometric observations of Nova Persei (1901) were started in September and are being continued.

Dr. W. H. Steavenson's Observatory, West Norwood.

During 1923, observations were made on 173 nights. The 6-inch refractor has been used chiefly for the observation of Novæ in their later stages. 374 observations of these bodies (including 124 of Nova Persei 1901) have been made during the year. In addition, the field of Tycho's Nova of 1572 has been observed on 53 nights. The results of photometric work on Nova Persei for the apparition 1922–23, and on other Novæ during 1922, have been communicated to the Society. The field of Anderson's reported Nova was observed and photographed several times during May and June without positive results.

β Ceti, observed early in September, appeared to be of its normal brightness.

Micrometric observations of the positions of Juno, Vesta, and Comet Baade were made on several nights during January.

Visual and photographic search was made for Comet D'Arrest on 15 nights during May, June, July, and August without result. The subsequent detection of the comet, nearly two months after perihelion, in South Africa closely confirms the search-ephemeris employed, and leads to the conclusion that the comet's magnitude was less than 11 until at least the middle of August, one month before perihelion. Considerable physical brightening must have taken place between August and November.

The usual physical observations of the major planets and of selected portions of the Moon's surface have been continued, and a few occultations have been observed.

Dominion Observatory, Ottawa, Canada.
(Acting-Director, R. Meldrum Stewart.)

The death occurred on 1923 December 28, of the Director, Dr. Otto Klotz, after a lengthy illness. He had never fully recovered from the voyage to Rome as Canadian representative at the meeting of the International Astronomical Union in 1922. He had been connected with the observatory since its founding in 1905, and was Director since 1917.

Meridian Work and Time Service.—Observations with the meridian circle were obtained on 129 nights. Observations on the working programme were finished during the course of the year, and another

programme has been begun. This comprises fundamental observations of all Backlund-Hough stars that can be reached in the latitude of Ottawa, together with the available stars of Boss's fundamental list, and some additional clock and azimuth stars; the clock stars are distributed in a belt extending about 25° on each side of the equator; observations of the sun, moon and principal planets will be included.

The time service has been maintained as in previous years. There are now 13 secondary master-clocks synchronised continuously from the observatory; these in turn control 575 clocks and dials of various kinds, including two tower clocks. Time-signals are sent out by telegraph and telephone, and the time recorded on the various seismographs at the observatory.

In addition to the receipt of the regular wireless time-signals from Annapolis and Lafayette, special signals sent out from Honolulu for the determination of Australian longitudes are being observed whenever possible.

Astrophysics.—As formerly, the 15-inch refractor has been used exclusively for radial-velocity work. Detailed studies of stars of the β Canis Majoris type have been continued and the field of investigation has been extended to the Cepheids, these having been found to have many similarities of behaviour with the former. Observations were made on 150 nights, 875 spectrograms being secured.

125 direct photographs were also obtained with the short-focus camera attached to the equatorial. These plates (field 18° in diameter) now aggregate well over 400, and contain a wealth of information concerning variable stars down to the 13th magnitude. So far, the photographic light-curves of eight variable stars have been determined with a fair degree of accuracy.

Solar Physics.—As was the case last year, observations have been handicapped by the unusual haziness during the year; only three cloudless days occurred, there being generally a considerable amount of haze. Some preliminary work was done with vacuum arcs; it is intended to secure five points on the solar disc along with spectra of standard arcs and low-pressure arcs at the same time; the difficulties have not yet been fully overcome. Additions have been made to the new double spectro-comparator to enable the readings of the micrometer drums to be seen beside the spectrum settings in the same eye-piece.

Terrestrial Magnetism.—Two parties were engaged in the field work of the magnetic survey, one at points along the Mackenzie River basin, the other in northern Manitoba. Fifty-one stations were occupied in all, the most northerly being within the Arctic circle and within 100 miles of the Arctic Ocean. Wireless equipment was used for the reception of time-signals for approximate determination of longitudes and for rating the chronometers used.

Seismology.—There are in use at this station two 200-gramme Bosch horizontal seismographs, two Milne-Shaw photographic horizontal instruments, and one Wiechert 80-gramme vertical seismograph with mechanical registration; also an undamped photographic deformation instrument.

During the year 308 earthquakes were recorded, their records read, and bulletins sent out to a mailing list of 230 stations.

One of the Milne-Shaw seismographs was used during a part of the year for experimental work at outside stations. It was set up for about six weeks at a point 8 miles west of Ottawa, and for a further period at a point about 30 miles south. A considerable amount of data was obtained for comparison with the records at Ottawa, and a report on this will be issued in due course.

The Dominion Astrophysical Observatory, Victoria, B.C.
(*Director, J. S. Plaskett, F.R.S.*)

The Staff.—The staff of the observatory consists of J. S. Plaskett, Director; W. E. Harper, Research Astronomer; Reynold K. Young and H. H. Plaskett, Astronomers; S. N. Hill, Assistant Computer; Miss H. R. Keay, Secretary; T. T. Hutchison, Night Assistant. During the summer vacation of five months W. H. Christie was employed as Observing Assistant.

Observing.—The observing weather during the past year has been excellent, better than for several years. The dome was opened and 1174 spectra obtained on 209 nights. On 138 nights, five or more spectra, total 1018, were obtained; on 71 nights less than five spectra, total 156, were obtained. On 18 of the nights, however, on which nineteen spectra only were made, there were exposures of several hours' duration on nebulæ and faint stars. As usual two hours on each Saturday evening have been given to visitors for observation with the telescope, but otherwise practically all the observing time has been given to photographing stellar and nebular spectra.

Researches.—The observing time of the Director has been chiefly spent on the completion of the O-type programme mentioned last year, but a few B-type spectra have also been secured. The measurement of the spectra and the preparation of the material for publication has occupied most of his time, but it is now ready for printing as vol. ii., No. 16, and will complete the volume. As a development of this work a paper on the H and K lines of calcium in the O-type stars was read at the December meeting of the Society. Considerable time was spent in the testing of two new camera objectives for the spectrograph, and a paper is appearing in the *Astrophysical Journal*. The orbit of an O-type binary, 56°2617, has also been completed and published. Mr. W. E. Harper and Dr. Reynold K. Young have spent the major part of their time in collaboration on the investigation of the spectroscopic parallaxes and absolute magnitudes of 1080 stars which is now nearly ready for publication, and will appear as vol. iii., No. 1, of the observatory publications. A shorter paper on improvements in methods and their application to the K and M stars is appearing in the forthcoming number of the *Journal R.A.S.C.* In addition, Mr. Harper has completed and published the orbit of Boss 6148 and the radial velocities of 125 stars. Dr. Young has completed one binary orbit, Boss 2463, and has measured and discussed the results of the Einstein plates at the

Australian eclipse. In collaboration with Professor Chant he has prepared a report on the results, now in press as vol. ii., No. 15. Mr. H. H. Plaskett completed the experimental work on the wedge method in astronomical spectrophotometry, measured and fully discussed the results, which contain some new and interesting data about the sun and stars. His discussion has been published and distributed as vol. ii., No. 12, of the observatory publications. A suggestion that the spectrum of nebulium is the band spectrum of a molecule such as hydrogen-helium, for example, and not of an unknown element, was sent as a letter to *Nature*, and a large amount of observational evidence on the nebulæ and associated stars has been accumulated in preparation for a further discussion of the nebular spectrum. Observing Assistant W. H. Christie took over some of the observing during the summer in the vacation absences of the staff, and brought up the card catalogue of radial velocities to date.

Publications.—The publications of the Dominion Astrophysical Observatory, vol. ii., Nos. 5 to 14, have appeared and been distributed, one is in press, and two large memoirs are practically ready for printing.

Helwan Observatory, Ministry of Public Works, Egypt.
(*Director, Mr. H. Knox-Shaw.*)

Owing to lack of staff the Reynolds reflector was not used during the year, except that five plates were taken in March in search of Jupiter's eighth satellite.

The rhythmic W/T signals transmitted from Lyons were observed regularly throughout the year, and also those from Bordeaux and Paris on a number of occasions. Transits were taken on 103 nights for the determination of local time in connection with this work. Several methods of reception of the signals were tried, and an automatic method, by which the beats of the clock cut out the W/T signals by altering the tune of the secondary circuit of the receiver, was eventually adopted for regular use. The results of the observations made up to June 30 are in the press.

The usual meteorological, magnetic, and seismological observations were made.

Nizamiah Observatory, Hyderabad.
(*Director, T. P. Bhaskaran, M.A.*)

The routine work of the observatory was continued on the same lines as in previous years.

Astrographic Equatorial.—Seventy-five photographs were obtained with this telescope for the catalogue and for miscellaneous purposes.

Decl. $-21°$. The whole zone is now complete. The printing of vol. v. of the *Hyderabad Astrographic Catalogue* dealing with this zone was commenced in 1923 May. The proof sheets of about half the volume have been read and passed for press. It is hoped that the publication will be ready for distribution during the ensuing year.

Decl. $-22°$. Twenty-two plates have been secured to replace some

of the less satisfactory ones already measured. The printing of the measures will be taken in hand as soon as vol. v. is finished.

Decl. -23°. Eighty-six plates have been measured to the end of the year, making a total of 160 plates measured in this zone. It is hoped that this section will be completed during 1924.

The Grubb 15-inch Telescope.—The necessary observations for the correct adjustment of the instrument have been completed, and some improvements for the convenient working of the telescope have been effected. It is proposed to devote this telescope at present to the regular observations of variable stars of long period.

Seismology. — A Milne-Shaw seismograph was acquired for the observatory in 1923 July. The machine was installed as a temporary measure in the basement room of the Astrographic Equatorial house, and systematic recording was commenced on 1923 September 9. The results will be communicated to the British Association Seismological Committee.

There has been no change in the senior staff of the observatory.

Kodaikánal and Madras Observatories.
(*Director, Dr. T. Royds.*)

The routine work with the photoheliograph, spectroheliographs, and the visual observations of solar phenomena was continued in 1923 as in former years. Under the auspices of the International Astronomical Union the Kodaikánal Observatory has this year begun to collect spectroheliograms from other observatories for those days when observations could not be made at Kodaikánal. This necessitates delay in the publication of the half-yearly bulletins, but it is hoped that the greater completeness of the data will more than compensate for the delay.

During February and March the spectroheliograph building was re-roofed. The grating spectrograph had to be dismantled whilst this reconstruction was carried out, and valuable time was taken up in its re-erection and re-adjustment, but spectroheliograms were taken each day as usual.

A device has been added to the H_{α} spectroheliograph for registering the H_{α} line step by step across the sun's disc. Only a few photographs were obtained during the year, partly owing to a temporary shortage of red-sensitive plates.

Studies of arc spectra have been made during periods of bad weather. Experimenters have previously observed that some arc lines become double or triple according to the amount of vapour present in the arc, and have suggested that this was an effect of the electric force due to atomic fields. This was chosen for further investigation, as it promised to furnish evidence of the atomic fields operating in the sun. If the tripling of arc lines is really due to atomic fields it ought to occur with many spectrum lines instead of being an exceptional occurrence. The visible spectra of many substances were therefore searched through, and each line was examined for the tripling effect when the amount of vapour was largely increased, but only about a dozen lines have been found to triple in the

visible spectra of many substances tried. The most suitable of these lines were thoroughly investigated, and, though the experiments are not quite completed, it appears likely that in all cases the apparent tripling is a misinterpretation of what is actually taking place.

Union Observatory, Johannesburg.
(*Union Astronomer, Dr. R. T. A. Innes.*)

There have been no changes in the staff. Professor E. Hertzsprung, of the Leyden Observatory, arrived on November 26 on a six months' visit, for the purpose of investigating variable stars in the Greater Magellanic Cloud and other Southern regions. Professor W. J. Hussey, of the Ann Arbor Observatory, Michigan, who is visiting South Africa to investigate the suitability of the climate for double-star work, spent a few days at the Observatory in November, before going to Bloemfontein.

The mechanical parts of the 26-inch refractor arrived at the Observatory in October, and the work of erection was at once commenced by the Public Works Department. A crown glass disk has been approved and is now being figured by Messrs. Grubb, but at the moment of writing an approved flint disk has not been procured.

There has been considerable correspondence with Dr. F. Schlesinger of the Yale Observatory, who proposes to erect a 26-inch refractor in the Southern Hemisphere for determination of stellar parallaxes. An official invitation from the Union Government to erect the telescope in the grounds of the Union Observatory has been sent to Dr. Schlesinger.

During the year Union Observatory Circulars, Nos. 56, 57, and 58, have been issued. With these were included 38 maps of portions of the Southern Sky.

Several attempts were made to photograph D'Arrest's comet with the Franklin-Adams Star Camera before perihelion passage, but apparently without success. After the rediscovery of the comet by Mr. Reid of Rondebosch in November, an orbit was computed and the position of the comet deduced for the times of the earlier photographs, with the result that very faint images of the comet were found on plates taken on September 5 and 7. The search-ephemeris prepared by Mr. F. R. Cripps was practically exact, but the comet was very much fainter before and at perihelion passage than it was two months after perihelion.

The minor planet (1) Ceres was observed visually over a long arc at the request of Mr. G. Merton.

In all, 109 occultations of stars by the Moon were observed by one or more observers; these have been fully reduced, but many of the adopted star-places could be improved upon, if recent observations were available.

During 1923 the clock-corrections used were obtained in the usual way, viz. from star-transits. A large number of comparisons was made with the W/T signals from oversea, principally with those from Bordeaux and Lyons, and it was found that the signals from Bordeaux can be received so easily and certainly that, commencing from 1924 January 1,

the Greenwich Sidereal Time, as signalled by Bordeaux, will be used for obtaining the clock-corrections. For convenience of use the sidereal clocks are kept $1^h\ 52^m\ 18^s$ in advance of the time received from Bordeaux, and the G.S.T. of an observation is obtained by deducting this amount from the clock time and then applying the correction indicated by the Bordeaux signals. Occasional meridian time-observations will still be made, but the results will not be used for obtaining the clock-corrections.

Our longitude, which is probably between $1^h\ 52^m\ 17^s{\cdot}85$ and $1^h\ 52^m\ 18^s{\cdot}00$, is now of importance only in computing the Moon's parallax, and an error of $0^s{\cdot}2$ is tolerable.

During the earlier part of the year (until May 15) the Union Astronomer was absent on leave in England, the Chief Assistant, Mr. H. E. Wood, M.Sc., being in charge.

The work in hand comprises (1) a Reference Catalogue of Southern Double Stars south of $-19°$ practically finished, but awaiting the completion of the Henry Draper Catalogue; (2) maps of the Southern Sky, 175 published, 23 in the Government printer's hands, and 358 still to be made; (3) photographic spectra of Nova Aquilæ, 1918, showing the red end including H_α; (4) an ephemeris of Neptune from 1846, based on Newcomb's Tables of that planet; (5) a re-reduction of the Transits of Mercury, also based on Newcomb's Tables; Newcomb's published investigations finished with the Transit of 1881, and the forty odd years since elapsed should furnish some evidence as to the constancy of the rotation of the Earth or otherwise; (6) a large mass of proper motions of faint stars determined in the Cape Astrographic Zone with the Blink microscope, and practically ready for publication.

Adelaide Observatory.
(*Director, Mr. G. F. Dodwell, Government Astronomer.*)

During the year 1923 the usual routine work (time service, seismology, etc.) has been carried out as already described in previous years' reports.

In addition, the magnetic elements have been determined at several first and second class field-stations.

In March a return visit to Cordillo Downs was made in order to obtain the comparison photographs required in connection with the Einstein photographs secured at the total eclipse of 1922 September 21.

These were obtained, and afterwards developed at Adelaide, and all the plates, both eclipse and comparison, were sent to Greenwich for measurement, advantage being taken of the Astronomer Royal's kind offer to do this.

The results have been communicated to the Society.*

Occasional wireless time-signals have been received, but owing to the time at which the world time-signals from Bordeaux are sent, it is difficult to arrange for their observation. It would be better for this part of the globe if such signals, on the highest power available, could be sent out twice daily.

* *M.N.*, 84, 150.

Melbourne Observatory,
(Director, Dr. J. M. Baldwin, Government Astronomer.)

During 1923 the attention of the meridian department has been devoted to overtaking the arrears of reduction of transit circle observations, and preparing the catalogues of stars which have been observed as reference stars for the astrographic plates of the Melbourne zones. This work is now so far advanced that it is intended to start, during the coming year, on a new observing programme, in which are included the Backlund-Hough stars culminating within 70° of the zenith.

Arrangements have been made for the printing of the first volume of the *Astrographic Catalogue*, containing the plates with centres at declination $-65°$ and $-66°$. It is already in the printer's hands, and the way seems clear for its publication in the near future. Two temporary lady clerks have been appointed to carry on the clerical work in connection with this and the later volumes of the catalogue.

Owing to the resignation of Mr. Hosking in June, the position of physicist has been vacant during the latter half of the year, and in consequence the work in Terrestrial Magnetism and in Seismology has been carried on under difficulty, and at the expense of other work. The vacancy has just been filled by the appointment of Mr. W. M. Holmes, M.A., B.Sc., who will enter on his duties early in 1924.

As in previous years, the 8-inch equatorial has been used for observing southern long-period variable stars, and 2028 observations made during 1923 have been forwarded to Harvard College Observatory and published in *Popular Astronomy*.

The magnetic work at Toolangi has been continued as in 1922.

After thorough examination of the Eschenhagen vertical variometer it was decided to replace the knife edges and saddle-shaped agates by steel points and agate planes. The results have been entirely satisfactory, and no difficulty has been experienced in maintaining a sensitiveness of about 2·5γ per mm. The important thing is to have the points quite sharp, and, in order to preserve them, to arrange that in adjusting there shall be as little raising or lowering of the points as possible, that motion over the planes should be avoided, and that there should be no large deflections, as these are liable to cause the points to chip off. Fresh points can be readily inserted, and by using a micrometer microscope to measure the distance the point is projecting, the adjustments of the balance can be made with very little disturbance to the points. After a little experimenting, sharp points could be readily prepared in the Observatory workshop.

The seismograph records for the first half of the year and the results have been forwarded to Oxford, but owing to lack of assistance the records for the latter half have not yet been examined systematically.

Sydney Observatory.
(Director, Professor W. E. Cooke.)

Astrographic Telescope.—The main routine work in 1923 was the taking and measurement of photographs for the *International Astrographic Catalogue*. Two star micrometers, occupying the time of four assistants, are now continuously employed. The most important feature of the year was the publication of the first two volumes (iii. and iv.) of this Catalogue. Vols. i. and ii. have been forwarded to the printer, but authority for printing has not yet been given. The Board of Visitors interviewed the Minister for Education, pointing out the urgency of the work, and it is probable that publication will be continued shortly. Several more volumes are nearly ready for the printer.

Transit Circle.—Zones -53° to -55° of the Sydney reference stars have been completed. Two volumes (-51° to -53° and -53° to -55°) are now ready for the printer, but authority for publication has not yet been granted.

Owing to the great difficulty of observing the faint stars the transit programme has been reconsidered. An offer of co-operation has been made by Dr. Schlesinger, and will probably be accepted. Directly after the completion of the -53° to -55° zone, we commenced the observation of the intermediary stars between -30° and -51°. Rapid progress is being made with this new programme, which we expect to complete within the next two years. By that time Dr. Schlesinger hopes to have a telescope erected in the southern hemisphere, and to have commenced his scheme of photographing the sky on very large plates, covering regions so extensive that the intermediary stars will suffice for the determination of the plate constants. We then hope to utilise these photographs, instead of the transit circle, for the determination of the positions of our reference stars.

Publication.—In addition to the two volumes of the *Astrographic Catalogue*, a report of the total solar eclipse of 1922 has been printed and distributed; also a description of a new form of sun-dial, which is easy of construction and will give standard clock time free from all corrections.

Wireless.—The time-signals transmitted from European and American stations are unsuitable for this side of the world, and an effort is being made to establish a regular daily connection amongst the observatories in the Pacific countries. The co-operation of the U.S. Naval Department has been enlisted, and on November 1 the high-power radio station at Pearl Harbour, Honolulu, commenced the transmission of two "scientific" signals daily. These consist of 300 dots at intervals of $0^s{\cdot}98$, starting at one minute past Greenwich noon and midnight. During the past two months they were inaudible in Australia, although the M.T. signals immediately preceding were perfectly clear. Letters and cablegrams were sent to Honolulu, and it appears that a change has been made in the method of transmission, because during the last few days of the year the scientific signals have been easily audible in Sydney. The transmission was originally arranged as an experiment, to extend over three months, but it is hoped that it will now be established

permanently. Circulars were sent from here to the observatories at Tokio, Zi-ka-wei, Manila, Batavia, Perth, Adelaide, Melbourne, Wellington (N.Z.), Santiago (Chili), Cordoba (Argentine), and La Plata (Buenos Aires), inviting co-operation. These observatories, with probably a few in the United States and Canada, form a rough circle about 180° in diameter, with the transmitting station in the centre.

Educational.—In addition to the usual course at the University, the Government Astronomer has conducted a tutorial class in astronomy. This appears to have been so successful that he has been invited to continue the class for another year.

At the request of the Department of Education the Government Astronomer is writing a series of articles on Elementary Astronomy for the *School Magazine*, and thus bringing the children into touch with the wonders of the sky.

Notes on some Points connected with the Recent Progress of Astronomy.

Discovery of Minor Planets in 1923.

Fifty-eight planets were discovered, or first announced, in 1923, as follows. The year is 1923 except in the first four cases, where it is given on the left hand:—

Letter and Number.	Date.	Magnitude.	Discoverer.	Letter and Number.	Date.	Magnitude.	Discoverer.	Letter and Number.	Date.	Magnitude.	Discoverer.
1901*b*	Nov. 5	...	...	NW	Aug. 9	12·8	KR	OQ	Sept. 13	14·0	KR
1903*a*	Jan. 18	...	...	NX	12	13·7	KR	OR	13	13·7	KR
1903*b*	18	...	...	NY	13	13·4	KR	OS	5	13·2	SB
1909 GX*a*	Apr. 22	...	...	NZ	12	13·6	KR	OT	5	13·0	SB
NF	Feb. 5	13·1	KR	OA	8	12·8	SB	OU	12	13·0	SB
NG	6	13·1	KR	OB	15	13·0	VA	OV	12	13·2	SB
NH	6	12·7	KR	OC	Sept. 11	13·5	MW	OW	14	13·8	JP
NJ 993	Jan. 12	14·8	GB	OD	11	13·4	KR	OX	Oct. 5	13·6	VA
NK	18	13·9	GB	OE	11	14	KR	OY	8	12·5	SB
NL 994	Mar. 18	13·5	KR	OF	11	13·9	KR	OZ	13	12·0	SB
NM	21	13·6	JP	OG	11	13·0	KR	PA	29	14·5	MW
NN	Apr. 9	13·2	KR	OH	13	13·5	KR	PB	29	15	MW
NO	19	13·7	VA	OJ	13	13·3	KR	PC	29	13	MW
NP 995	June 8	12·8	SB	OK	13	13·2	KR	PD	31	14·5	MW
NQ	July 12	13·6	KR	OL	13	13·2	KR	PE	31	13·4	KR
NR	12	13·3	KR	OM	13	13·3	KR	PF	Nov. 12	13·0	KR
NS	12	13·2	KR	ON	13	13·0	KR	PG	6	12·8	VA
NT	May 23	12·4	GP	OO	13	13·9	KR	PH	Dec. 1	14	MW
NU	Aug. 6	13·7	KR	OP	13	13·6	KR	PJ	29	14	MW
NV	8	13·6	KR								

The initials stand for: VA = V. Albitzky, Simeis; SB = S. Beljavsky, Simeis; JP = J. Palisa, Vienna; GP = G. H. Peters, Naval Observatory, Washington; KR = K. Reinmuth, Königstuhl; GB = G. van Biesbroeck, Yerkes Observatory; MW = M. Wolf, Königstuhl.

The first 4 planets were found on re-examining old Königstuhl plates; images were found for the following dates: 1901*b* on 1901

November 5, 12, 16; 1903*a* on 1903 January 18, 22, 31; 1903*b* on 1903 January 18, 22; 1909 GX*a* on 1909 April 22, May 8, 9, 11.

NM is perhaps identical with 658 Asteria, and NQ with 903 Nealley. 995 NP is probably identical with 1903 NF, and OA with 1907 BL. OZ is possibly 699 Hela. PB, PC, PH were noted as somewhat doubtful. NT, OJ, OK, ON were subsequently found on Simeis plates of May 14, September 10, September 5, September 5 respectively. OS was independently found by K. Reinmuth on September 13.

The following planets, unnumbered at the date of the last Report, have received permanent numbers: Anacostia = 980, Σ92 = 981, MD = 982, ME = 983, MH = 984, MO = 985, MQ = 986, MR = 987, MT = 988, MW = 989, MZ = 990, NB = 991, ND = 992. NB, NC, ND, NE should be added to the list of discoveries in 1922.

The following planets have been named: 754 *Malabar,* 849 *Ara,* 877 *Walküre,* 916 *America,* 922 *Schlutia,* 972 *Cohnia.*

H. Osten gives in *Astr. Nach.*, 5248, a careful determination of the orbit of 29 Amphitrite, using observations from 1825 to 1921; A. Michailowski studies that of 263 Dresden in *Astr. Nach.*, 5215, using observations from 1886 to 1915. A. Klose contributes to *Astr. Nach.*, 5232, an interesting investigation of the gaps in the orbits at the points of commensurability with Jupiter.

The recovery of the long-sought planet 132 Aethra was mentioned in a footnote in the last Report. The planet was well observed till May. *Astr. Nach.*, 5241, contains the following orbit, deduced from the recent observations by W. Luther. Elements of the interesting new planet PE, by G. Stracke, are added.

	Aethra.	Planet PE.
Epoch	1922 Dec. 22·5 G.M.T.	1923 Nov. 5·5 G.M.T.
M	330° 27′ 12″·2	354° 54′ 45″·4
ω	253° 27′ 49″·6	182° 58′ 19″·2
Ω	259° 16′ 26″·3	229° 17′ 9″·6
i	25° 9′ 10″·5	16° 18′ 4″·0
ϕ	22° 28′ 15″·5	28° 2′ 18″·5
μ	838″·61965	782″·065
Equinox	1923·0	1923·0
Period	4ʸ·231	4ʸ·537

PE was at first taken for a comet, as the earliest photograph had a nebulous appearance, but this was not confirmed on careful visual scrutiny. The later observations suggest a shorter period than that given above, probably near 4 years. The perihelion distances given by these orbits are Aethra 1·6161, PE 1·4526; both are smaller than the aphelion distance of Mars.

The average period of Aethra from 1873 to 1923 is almost exactly $4\frac{2}{9}$ years, so that an interval of 38 years closely reproduces the conditions of observation. The next opposition will be on 1924 July 9, when the position will be R.A. $19^h\ 13^m$, S. Decl. 3° 10′, magnitude 13·4.

The present opposition of 433 Eros is interesting, as it is one 7-year

cycle before the close approach of 1931 January. Recent observations show that the ephemeris by F. E. Seagrave in *B.A.A. Handbook* needs corrections of $+10^{sec}$, $-5'$.

An estimate from the recent observations makes the perihelion passage of Eros occur on 1931 January 17, some $5\frac{1}{2}$ days before the Earth passes the longitude of the planet's perihelion. The interval in 1938 will be 10 days in the other direction.

The National Research Council at Washington has published a useful volume, edited by Professor A. O. Leuschner, which summarises the various researches made on the perturbations of 21 planets, including the 4 bright ones, Eros, and the 6 Trojans. Appendix II. of the Annals of Tokyo Observatory contains a discussion by Professor Hirayama of five families of asteroids, containing respectively 25, 23, 15, 13, 57 members, whose original orbits are shown to have been so close to each other that a common origin is probable in each case.

Reference should once more be made to the valuable work done by Marseilles Observatory in issuing circulars and ephemerides, which are of great assistance in keeping the vast host of minor planets under regular observation.

The present year will almost certainly see the list of planets with assigned numbers pass the figure 1000; the number known to exist has exceeded that total for several years. A. C. D. C.

Report on Comets in 1923.

Observations of two of the comets mentioned in the last Report were continued in 1923. Dr. Baade was able to follow his Comet 1922 *c* till last December, when it was of magnitude 15·7, and far outside the orbit of Jupiter. Prof. van Biesbroeck also obtained observations of it at Yerkes Observatory during the summer.

Skjellerup's Comet, 1922 *d*, passed perihelion on 1923 January 3, so its permanent designation is 1923 I. It was followed till the end of February.

Comet 1923 *a*, 1923 III (Bernard-Dubiago), was discovered independently by at least four people. The first to see it was Señor Arturo Bernard Acin, a physician of Colmenarejo, Madrid; on October 11 at 16^h while observing the variable U Monocerotis, he detected the comet, which was then in R.A. $7^h\ 31^s$, S. Decl. 8°. He described it as round, 6′ in diameter, easily visible with prism binoculars; he observed it again on October 12, 15, and 16, its motion being very rapid to the south-east. Professor Dubiago found it independently at Kasan on October 14, and obtained an accurate position. There was, unfortunately, great delay in the circulation of these announcements, and the comet was below the southern horizon before they were received in England.

It was found (apparently independently) in South Africa about November 4. Observations were obtained at the Cape Observatory on November 5, 6, 7; the approximate elements given below were deduced there, presumably by Dr. Halm, and telegraphed to Copenhagen.

No telegraphic information had been sent to New Zealand; Mr. F. J. Morshead, of New Plymouth, discovered it independently on November 6 in the same telescopic field as γ Trianguli Australis (S. Decl. 68° 24′); he described it as faint. Owing to cloudy weather and moonlight he could not find it again till November 29 and 30. On the latter evening it was in the field with ϵ^2 Arae, and moving towards θ Scorpii. It had attained its highest south declination, about 72°, on November 2. It may possibly still be observable when it comes north again in the spring. It made its nearest approach to the Earth (0·4 of a unit) about October 18.

The designation Comet 1923 *b* was at first given to an object photographed by Herr Reinmuth at Königstuhl on October 31, which he described as nebulous. But further observations showed that it is a minor planet (PE) with an orbit of the Aethra type. The designation 1923 *b*, 1923 II, was transferred to the comet found by Mr. William Reid at Rondebosch, Cape Town, on November 10. He described it as fairly large, very faint (magnitude 11), slightly brighter in the middle, but with no definite nucleus. It appeared like a faint star cluster with many stellar points. After the observation of December 1 at the Cape Observatory had been telegraphed to Europe, it was recognised that the comet was identical with D'Arrest's Periodical Comet, which had been searched for in vain in August and September. Two independent, but almost coincident, computations of the perturbations by Jupiter had been made; the first by Mr. F. R. Cripps, the other by Professor A. Dubiago and A. Lexin at Kasan (*Ast. Nach.*, No. 5241). The actual time of perihelion was about 1·4 days later than Mr. Cripps' prediction, and 0·44 days later than the other, which is printed below. The discordance is very small considering that the comet was not seen in 1917, and made a fairly near approach to Jupiter (least distance 0·5 of a unit) in 1920.

After the identity was established, Mr. H. E. Wood re-examined some plates taken at Johannesburg in September, and succeeded in finding two faint images of the comet (magnitude about 14) as follows:—

	G.M.T.	R.A. 1923·0.	S. Decl. 1923·0.
	d h m s	h m s	° ′ ″
Sept.	5 6 53 21·3	17 34 28	15 33 34
	7 6 20 33·2	17 39 57	16 31 54

The comet was then near perihelion, and the theoretical brightness was considerably greater than in November; but actually it was 3 magnitudes fainter, showing that some remarkable physical change took place in the comet in the interim.

An observation was obtained by M. Chofardet at Besançon on December 6, when the magnitude was estimated as 12½ to 13; it appeared as a small, ill-defined nebulosity, at most 20″ in diameter, without definite nucleus.

It is noteworthy that search for D'Arrest's Comet had been abandoned before November. Mr. Reid was simply making his customary search for new comets, and did not suspect the nature of his discovery till three weeks later.

The Cape elements of Comet Bernard-Dubiago, and the predicted Dubiago-Lexin elements of D'Arrest's Comet, are as follows:—

	Bernard-Dubiago.	D'Arrest.		D'Arrest (*contd.*).
T	1923 Nov. 16·70 G.M.T.	1923 Sept. 14·7149 G.M.T.		ϕ 38° 1′·1
ω	254° 32′	174° 1′·5		μ 534″·783
Ω	227° 36′	143° 31′·7	1925·0	log a 0·547886
i	114° 17′	18° 3′·9		Period 6·63483 years.
log q	9·8976	0·132315		

Mr. C. J. Merfield's computation of the perturbations of Comet Pons-Winnecke, 1921 to 1927, appeared in *M.N.*, 83. He finds the date 1927 June 20 for the next perihelion passage; the approach to the Earth at the end of June will probably be much closer than that in 1921.

A. C. D. C.

Solar Activity in 1923.

Sun-spots.—Considering the year as a whole, the decline in spot activity has been considerable. The mean daily spotted area is 55 units, as compared with 252 units in the year 1922. On about 180 days no spots were visible, as compared with 109 spotless days in the previous year. High latitude spots, from 25° to 30°, although not frequent, have now become a definite feature, accompanying occasional spots seen in the neighbourhood of the Sun's equator. The characteristics for the year are, therefore, decidedly those of sun-spot minimum, and an increase of spot activity may be expected within the next year.

No spot group calls for special attention on account of its extent. The largest was that seen on the Sun's central meridian on June 28 in latitude 8° N. Its mean area, however, was only about one-seventh that of the largest of the groups seen at the maximum of the cycle.

Several of the high-latitude spot groups have been of "bipolar" type and have persisted for several days. The Mt. Wilson observers have therefore had the opportunity of testing whether there has been a reversal of spot polarities as observed at the last minimum. Each high latitude, or new cycle, group of spots has shown polarities opposite to those of the low latitude, or waning cycle, and there appears to be no doubt as to the reality of a general reversal of spot polarities at this stage of the last two solar cycles.

H. W. N.

The Prominences.—The mean daily areas of prominences in square minutes of arc derived from the Kodaikánal photographic records are as follows:—

	North.	South.	Total.
1923 January–June . . .	2·48	2·10	4·58
July–December . . .	2·22	1·96	4·18

The mean daily numbers were 15·8 and 15·1 respectively in the two half-years.

Both areas and numbers of prominences show an increase as compared with the figures for 1922.

The distribution in latitude was identical during the two periods of six months, and shows very little change from that of the year 1922.

Only eight metallic prominences were recorded during the year, of which six were in the northern hemisphere. A northern preponderance is also shown in the case of displacements of the hydrogen lines at the limb, of which 357 were recorded during the year as against 315 during 1922. The displacements towards red were as usual in excess of those towards violet.

The activity continued to be feeble with regard to prominences projected on the disc as absorption markings, but there were indications of a revival at the end of the year. T. R.

Solar Research in 1923.

Magnetic Fields.—The most notable solar occurrence of the year is the reversal of polarity of the high-latitude spots of the new cycle beginning at the current minimum, announced from Mount Wilson. A reversal in the opposite sense had occurred in 1912 at the minimum then current, and such reversals might be an essential phenomenon recurring at every change of cycle. The anticipation is confirmed by fully-observed bipolar groups from 1923 August onwards. The preceding member in the northern hemisphere has south-seeking polarity for the new cycle. An account is given by G. E. Hale, *Nature*, 1924 January 19 (Supplement), with some comments by H. F. Newall. Summaries of Mount Wilson magnetic observations, including those of the new cycle, are given in *P.A.S.P.*, **35**, 63, 123, 172, 219, 264, 330.

Comparisons of solar and terrestrial magnetic phenomena in recent years are given by A. L. Cortie (*M.N.*, **83**, 204) and B. G. Swindells (*M.N.*, **83**, 215).

Sun-spots, Faculæ, and Prominences.—New measures of the speed of rotation of calcium filaments about the sun's axis are given by L. d'Azambuja, *C.R.*, **176**, 950. The rotation-speed, as computed from one or more complete rotations, is the same as that of spots, and the same for different filaments; and it shows a marked polar retardation. But as computed from positions during a single passage over the disc, the speed is apparently much greater. This is accounted for as an effect of perspective due to the protruding mass of gas forming the filament being seen in projection against the disc. By attributing heights to the two edges of the filament varying up to 90″, the two measures of rotation-speeds are brought into harmony, and the heights deduced from the rotation-speeds are in general agreement with the heights of the corresponding prominences observed during the passage of the filament over the limb.

The number and distribution of faculæ observed in the period 1874–1917 are studied in a communication from the Royal Observatory, Greenwich, *M.N.*, **84**, 96. They are shown to exhibit the same general features as sun-spots, but the faculæ-zones are on the average 15° broader than the spot-zones; there is also a zone of polar faculæ, showing slight concentration in latitude 70°. The paper contains

remarks on the relations of faculæ to spots. Mean areas of spots for two years are published by the same observatory in *M.N.*, **83**, 345, and **84**, 30.

Observations of prominences made at Kalocsa during 1886–1917 are published by J. Fenyi in *A.N.*, 5252. In *A.N.*, 5254, A. Stentzel makes comments on the current spot-minimum. Some criticisms of T. J. J. See's explanation of sun-spot phenomena are made by F. Nölke in *A.N.*, 5216.

A new scouting spectroscope for prominences for use with the 40-inch Yerkes refractor is described by O. J. Lee, *Astrophys. Journ.*, **57**, 121; it is furnished with a slit, curved to fit the sun's limb. A form of prism-micrometer designed for the measurement of the depth of the chromosphere is described by P. Fox, *Astrophys. Journ.*, **57**, 234. Preliminary observations gave a depth of 10″ for Hα and 8″ for D_3.

Corona.—The observations of the coronal spectrum made at the eclipse of 1922 September 21 are summarised by J. H. Moore, *P.A.S.P.*, **35**, 59. They confirm the previous suspicion that the coronal lines are fainter at sun-spot minimum than at maximum. Spectroscopic evidence of radial motion in the outer corona is given by the same writer in *P.A.S.P.*, **35**, 333. The eclipse observations of 1922 gave displacements of +26 km. at points 20′ E. and W. of the sun's limb. These are attributed to a radial motion of the particles outwards from the sun, of the order of 20–30 km. per sec., the observed displacement being that arising from the earthward constituent of the sunlight scattered by the particles. In *P.A.S.P.*, **35**, 163, W. W. Campbell, J. H. Moore, and R. H. Baker find that the axis of symmetry of the coronal streamers observed during 1898–1922 coincides with the rotation axis of the sun and not with the magnetic axis.

Spectroscopic Work.—A summary of the Kodaikánal work on the shift of lines in the solar spectrum is given by J. Evershed, *Observatory*, **46**, 299. The absence of pressure effects is emphasised. As compared with Einstein's predicted shift to the red, there is an excess shift at the limb for high-level Fe lines in the ultra-violet, but the wave-lengths are not constant in time. The weaker Fe lines, which have constant wave-lengths, gave shifts in good agreement. The D lines gave a shift of ·0156 A as compared with the Einstein shift of ·0124 A, but it is noted that emission D lines (with which the comparison was made) are always displaced a few units to the violet in the third place with respect to the absorption lines. Observations of the light reflected from Venus have now yielded results in agreement with those of direct sunlight.

The Mount Wilson observations are dealt with similarly by C. E. St. John in *M.N.*, **84**, 93. He concludes that the pressures are everywhere negligibly small. The observational material consists of 300–400 Fe lines which have been observed in the arc *in vacuo* and under atmospheric pressure, and in the solar spectrum. The observed shifts at the centre of the disc exceed the Einstein predicted value by some 50 per cent. for the high-level lines, but the differences decrease with level, changing sign and amounting to minus 30 per cent. for the low-level lines. It is impossible to account for the whole shifts in terms of upward and downward currents, so that the Einstein shift is certainly

present, but the residuals are attributed to such currents, varying from downward velocities of 0·3 km. per sec. for the high-level lines to upward velocities of 0·2 km. per sec. for the low-level lines. The increased shifts at the limb are attributed to the effect of differential scattering in widening the red edges of lines.

A critical summary of the earlier work on the Einstein shift is given by F. Croze, *Journ. de Phys.*, **4**, 115, and a fuller account in *Annales de Phys.*, **19**, 93.

Interferometer measures by H. D. Babcock of the green auroral line give a wave-length of 5577·350 ± ·005 I.A. (*Astrophys. Journ.*, **57**, 209). Other studies of the auroral and night-sky spectrum are given by Lord Rayleigh, *Proc. Roy. Soc.*, **103A**, 45, and by L. Vegard, *C.R.*, **176**, 947.

*Solar Radiation.**—The extraordinary drop in the solar constant values during 1922 and early 1923, as measured at the Smithsonian stations at Mount Harqua Hala, Arizona, and Mount Montezuma, Chile, is commented on by C. G. Abbot and colleagues in *Proc. Nat. Acad. Sci.*, **9**, 194. Previous to the beginning of 1922, the prevailing values were exceeding the mean of 1·94, but after that they steadily decreased to about 1·91. Nothing so marked has occurred since solar constant determinations began in 1905. Further determinations of the solar energy curve at Mount Wilson with the spectro-bolometer are described by the same writers in *Smithsonian Misc. Contr.*, **74**, No. 7.

The intensity distribution in the solar spectrum has been measured by H. H. Plaskett in sixteen places where there are no solar lines of intensity exceeding 0 on Rowland's scale, using the neutral-tinted wedge method (*Pub. Dom. Astrophys. Obs.*, **2**, 213). He finds that the observed intensities corrected for transmission through the earth's atmosphere fit a black-body radiation curve in the region 4000 A to 6700 A; the observations, which refer to the centre of the disc, lie within the curves corresponding to temperatures of 6300° and 7000°. No such fall-off in intensity on the violet side of 4700 A was observed as was found by C. G. Abbot and his colleagues, and by J. Wilsing, in their determinations of the solar energy curve, and the difference is ascribed to the effect of absorption lines in the observations of the latter investigators.

Measures of the sun's ultra-violet radiation by means of a silver filter, transmitting in the region 3150–3200 A, have been made by G. M. B. Dobson, *Proc. Roy. Soc.*, **104A**, 252. Large day-to-day variations, considerably exceeding the errors of observation, were found in the solar intensity in this region outside the earth's atmosphere. The average contrast between points on the sun's disc, 12½ per cent. and 87½ per cent. from the centre, was found to be about 53 per cent., in

* Reference was accidentally omitted from last year's summary to the important work by C. Fabry and H. Buisson, *C.R.*, **175**, 156 (1922), on the solar energy-curve in the ultra-violet. Measures were made by comparing the solar intensity with the intensity from the positive crater of the arc, which was taken to correspond to a temperature of 3750°. Atmospheric transmission coefficients were determined. The solar intensity at the centre of the disc, measured at five places free from absorption lines in the region 2922–3940 A, was found to correspond very closely to that of a black body at 6000°.

agreement with the earlier observations of Schwarzschild and Villager. The connection of the results with various solar and terrestrial phenomena is discussed.

In *Journ. de Phys.*, **4**, 115, J. Duclaux and P. Jeantet discuss the causes of the limitation of the solar spectrum to 2900 A, and surmise that there should be a narrow band of transmission near 2100 A, between the end of the ozone absorption and the beginning of the ammonia absorption. This has been sought for by P. Lambert, G. Déjardin, and D. Chalonge, observing at the Vallot Observatory, Mont Blanc (height 4300 m.), but no trace of re-appearance of the solar spectrum was observed (*C.R.*, **177**, 757).

Measures of the decrease in the red proportion of the solar intensity reaching the earth as between Europe and the Equator have been made by L. Gorczinski, *C.R.*, **177**, 754.

The colour-temperatures of sunlight and moonlight have been determined by W. E. Forsythe, using an optical pyrometer with monochromatic screens, *Nature*, **111**, 533. The colour-temperature of moonlight is compared with its brightness-temperature.

Theoretical.—In *Proc. Amsterdam Acad.*, 26, 329, W. H. Julius and M. Minnaert give a detailed application of the anomalous dispersion theory to the broadening and mutual influence of Fraunhofer lines at the limb. They mention that anomalous molecular scattering cannot have any share in the production of the general deflection of solar lines to the red.

R. Lundblad has deduced the temperature distribution in the outer layers of the sun from the observed darkening towards the limb, *Astrophys. Journ.*, **58**, 113. He ascribes an actual temperature of 4500° to the outermost layers, finds no evidence of scattering in the infra-red or visible regions, and concludes that the outer layers are in radiative equilibrium.

A memoir by B. Lindblad, *Nov. Act. Reg. Soc. Sci. Upsal.*, **6**, 1, contains a fresh numerical solution of the integral equation for radiative equilibrium, following Schwarzschild. In the second part of the memoir he re-discusses the darkening of the sun towards the limb in the light of criticisms made by E. A. Milne (*Phil. Trans.*, 223A, 201). Using the Smithsonian observations for 1913 (sun-spot minimum), he finds they can be brought into agreement with calculation if it is assumed that 16 per cent. of the sun's photospheric radiation is returned by the layers causing the Fraunhofer lines. The variation of absorption-coefficient with wave-length is also taken into account.

A further reference on this subject is R. Dietzius, *A.N.*, 5212.

A. H. Compton has recently proposed a quantum theory of the scattering of radiation by electrons, which results in a shift of the wave-length to the red for an electron at rest. Scattering by free electrons in the solar atmosphere is suggested by him as the cause of the centre-limb shift to the red in *Phil. Mag.*, **46**, 897. Scattering and absorption by free electrons on the classical theory, and its application to the sun, is considered by J. Q. Stewart, *Nature*, **111**, 186, and *Pop. Astron.*, **31**, 253, and pursued further by M. N. Saha, *Nature*, **112**, 282. The continuous spectrum of the corona is attributed by W. Anderson to an

electron atmosphere (*A.N.*, 5224); other solar problems are discussed by him in *A.N.*, 5239, and *Zeits. für Phys.*, **20**, 166.

By comparing its luminosity with the twilight luminosity of the earth's atmosphere, an upper limit to the density of the corona is estimated by B. Fessenkoff (*A.N.*, 5238). He finds the density cannot exceed 10^{-4} to 10^{-5} of the density of the earth's atmosphere at 100 km. height.

In *A.N.*, 5220, P. Tschirwinsky suggests a theory of vortex circulation in the interior of the sun, based on certain experimental analogies. De Saussure points out that the observed solar diameter must exceed the true value, owing to the Einstein deflection (*A.N.*, 5235). This, however, is erroneous.

E. A. M.

Stellar Spectroscopy in 1923.

Novæ.—A photographic-photometric study of Nova Cygni III. (1920) is published by P. Davidowitsch in *A.N.*, 5223. The colour-index, which was small and positive during the rapid decline, later became negative, in spite of the reddish-orange colour which the star assumed. This sharply differentiates the Nova from ordinary stars, and precludes any attempt to derive the effective temperature from the colour-index. W. H. Robinson in *A.N.*, 5227, points out that the same phenomenon was observed with Nova Persei (1901) and noted in *M.N.*, **62**, 198. An opposite march of colour-index for Nova Aquilæ III. (1918) is given by H. Shapley in *Proc. Nat. Acad. Sci.*, 9, 39, together with other particulars of the light and colour variation.

Photometric observations of various Novæ are given by W. H. Steavenson, *M.N.*, **83**, 160 and 397, B. Fessenkoff, *A.N.*, 5223, W. Rabe, *A.N.*, 5240, and K. Graff, *A.N.*, 5245.

In *P.A.S.P.*, **35**, 261, E. Hubble comments on Belanowsky's Nova in M87, with reference to some peculiarities of the nebula. Observations of Nova No. 20 in the Andromeda nebula are given by M. L. Humason, *P.A.S.P.*, **35**, 124. In *P.A.S.P.*, **35**, 166, C. O. Lampland announces the discovery of a Nova in the spiral M83; further observations are given in *Pop. Astron.*, **31**, 648.

Plates forming a pictorial study of Nova Geminorum II. are published by R. H. Curtiss in *Pub. Obs. Mich.*, **3**, 253.

In *P.A.S.P.*, **35**, 95, K. Lundmark discusses the parallaxes of the Novæ, deducing that the mean value of the absolute magnitude at maximum is $-7^{\cdot}1$, and that the range in general does not exceed 11 magnitudes. He discusses the suggestion that the Nova stage may be an episode in the life of every star. The theory of Novæ is dealt with also by H. Vogt, *A.N.*, 5212, and by E. Belot, *C.R.*, **177**, 947.

Photometry and Spectro-photometry.—An account of a method of determining the continuous spectra of stars by measurement of the intensity distribution in spectrograms with a photo-electric cell is given by R. A. Sampson in *M.N.*, **83**, 174. The details of reduction and calibration are described in full, and preliminary results of observations on stars are given in the form of a table of effective temperatures, the

temperature of Capella being taken at 5500°. The temperature of γ Cassiopeiæ, for which previous investigators had found anomalously low values, is determined as 16,900°.

Applications of Merton and Nicholson's neutral-wedge method of spectro-photometry to the continuous spectra of the sun and stars are described by H. H. Plaskett in *Pub. Domin. Astrophys. Obs.*, 2, 213. The colour-temperatures of 6 stars, from γ Cassiopeiæ (Boe, 15,000°) to β Geminorum (Ko, 5000°–5500°), are given, and some comments are made on the anomalies in the intensity distribution for early-type stars.

The results of thermo-couple observations of the distribution of intensity in stellar spectra, made by using suitable transmission screens, are given by W. W. Coblentz in the form of a table of stellar temperatures in *Pop. Astron.*, 31, 105. The stars observed range from ε Orionis (Bo, 13,000°–14,000°) to α Orionis (Ma, 2800°–3300°).

The photographic spectro-photometric observations of Rosenberg and the visual observations of Wilsing and his colleagues have been re-analysed by A. Brill in great detail in a series of papers (*A.N.*, 5222, 5223, 5234, 5254) and compared with other scales. A discussion of Wilsing's method of temperature-determination by reducing the star-colour to that of a comparison lamp is given by G. Schnauder (*A.N.*, 5246). In *A.N.*, 5202, B. Harkanyi examines the absolute magnitudes of the stars whose temperatures were determined by Wilsing, and finds that the absolutely brightest stars of a given type have the smallest effective temperatures.

The use of λ_{eff} and λ_{min} as colour-equivalents is discussed by B. Lindblad (*M.N.*, 83, 97) and K. Lundmark and W. J. Luyten (*M.N.*, 83, 470), and in *M.N.*, 83, 503, Lindblad discusses similarly the use of cyanogen absorption and the contrast on the two sides of the G absorption.

In *A.N.*, 5240, H. Osthoff gives brightness estimates of some red stars. In *B.A.N.*, 37, and *Proc. Amsterdam Acad.*, 26, 12, E. Hertzsprung discusses the magnitude equation in Osthoff's colour-estimates; in the former paper he also gives the colours of some early-type stars which are yellower than normal, and surmises that these will prove to be *c*-stars.

Brightnesses and colours in the cluster M34 are given by K. Graff (*A.N.*, 5250). Colour-indices from photo-visual magnitudes, including a correction to the colour-index of Nova Aquilæ III., are published by E. S. King, *Proc. Nat. Acad. Sci.*, 9, 345.

Revisions of Harvard photographic magnitudes are noted in *Harv. Bull.*, 781.

Studies of stars in the Pleiades have been made by C. Nordmann and C. le Morvan with their three-colour photometer (*C.R.*, 176, 1054). An application to parallax determinations is suggested.

A photo-electric photometer constructed at the Lick Observatory is described by Miss E. Cummings, *L.O.B.*, 349.

Spectroscopic Parallaxes.—A spectroscopic method for determining the parallaxes of the B-type stars has been investigated by W. S. Adams and A. H. Joy (*P.A.S.P.*, 35, 120, and *Astrophys. Journ.*, 57, 294). Curves are found correlating measured spectral-type with absolute magnitude, and used to determine the parallaxes of 300 stars. The luminosities and spectroscopic parallaxes of 500 stars of types Fo to

Mb, determined at the Norman Lockyer Observatory, are published in a valuable memoir by W. B. Rimmer (*Mem. R.A.S.*, **72**, 113). The lines employed were chiefly those of Sr^+ and Ti^+ compared with lines of Fe and Ca. The results are compared with the Mount Wilson determinations, and the systematic and average differences are found to be satisfactorily small. In *Harv. Circ.*, 243, H Shapley and A. Ames give the distances of 233 southern stars of type Ko determined from objective prism spectra, and in *Harv. Circ.*, 246, H. Shapley gives the distances of 116 southern stars of types G5, K2, and K5 determined similarly. A preliminary announcement of the method and results of absolute magnitude determinations made at the Dominion Astrophysical Observatory from spectra obtained for the Boss programme of radial velocities is given by W. E. Harper and R. K. Young (*Pop. Astron.*, **31**, 577).

Systematic errors arising from the use of spectroscopic parallaxes in statistical investigations are discussed by A. S. Eddington and Miss A. V. Douglas (*M.N.*, **83**, 112), W. S. Adams and G. Strömberg (*M.N.*, **83**, 474), and F. H. Seares (*M.N.*, **84**, 15). A comparison of dynamic and spectroscopic parallaxes for doubles showing relative motion is made by H. N. Russell, W. S. Adams, and A. H. Joy in *P.A.S.P.*, **35**, 189. In *A.N.*, 5261, R. Hess discusses the accuracy of spectroscopic parallaxes, and in *Harv. Bull.*, 788, a reply is made to Van Rhijn's criticisms of the accuracy of spectroscopic parallax methods in connection with giants of types K and M; the order of stars arranged according to the intensity of $\lambda 4215 Sr^+$ is found to be the same as that according to proper motions.

The theoretical significance of spectroscopic parallaxes is receiving attention. In *Astrophys. Journ.*, **55**, 239 (1922), H. N. Russell had pointed out the dependence of spectroscopic parallax on the density of the stellar atmosphere, and had made an application to the determination of masses; a comment on this is made by E. A. Milne, *Camb. Phil. Trans.*, **22**, 511. In *B.A.N.*, **19** (1922), A. Pannekoek had explicitly drawn attention to the fact that line intensities for stars of given temperatures should be correlated with pressures, and hence with surface values of gravity rather than with absolute luminosities; the same point is emphasised by A. S. Eddington, *Nature*, 1923 May 12 (Supplement). Pannekoek pursues the consequences of this in *Observatory*, **46**, 304. He shows that trigonometric and spectroscopic parallaxes may be expected to differ when the mass of the star differs from the mean mass of the group used for calibration, and that a closer correlation of line intensities with absolute magnitudes should be obtained if the luminosities were calculated from hypothetical parallaxes in the case of double stars.

The Theory of Spectra and High-Temperature Ionisation.—Owing to its astrophysical importance mention must be made of A. Fowler's achievement in discovering the series spectrum of trebly-ionised silicon (*Proc. Roy. Soc.*, **103A**, 413). Series relations in the spectra of chromium and molybdenum have been found by M. A. Catalan, *C.R.*, **176**, 84, 247, 1063; reference to the same investigator's work on the spectrum of manganese (*Phil. Trans.*, **223A**, 127) should have been

made in last year's summary. H. H. Plaskett has suggested that the nebular lines may be due to a hydrogen-helium molecule, and has found evidence of groupings in accordance with the laws of formation of band spectra (*Nature*, **112**, 392; *Pop. Astron.*, **31**, 658).

A. A. Noyes and H. A. Wilson have obtained experimental confirmation of the ionisation theory by determining ionisation potentials from flame conductances (*Astrophys. Journ.*, **57**, 20).

H. N. Russell has repeated R. d'E. Atkinson's calculations of the dissociation of titanium oxide (*Pop. Astron.*, **31**, 22), and finds a partial pressure for Ti and O together of 10^{-4} atmosphere, in the stellar atmospheres concerned. From the Stark effect he calculates the density in the region giving the continuous spectrum to be less than 10^{-7} gram. cm.$^{-3}$, and the pressure to be less than 5×10^{-3} atmosphere for stars of type F and earlier.

J. Q. Stewart has used the differences in temperature between giants and dwarfs to calculate the ratio of the pressures in their atmospheres, and finds the ratio in agreement with the ratio of the surface values of gravity (*Pop. Astron.*, **31**, 88).

Some criticisms of H. H. Plaskett's treatment of the theory of high-temperature ionisation are made by E. A. Milne (*Observatory*, **46**, 113). The general theory is discussed further by R. H. Fowler (*Phil. Mag.*, **45**, 21) and by M. N. Saha (*Phil. Mag.*, **46**, 534).

In *M.N.*, **83**, 403, R. H. Fowler and E. A. Milne have applied the theory of statistical equilibrium in connection with the ionisation theory to the maximum intensities of absorption lines in the stellar sequence of spectra. The Balmer lines will have a maximum at 10,000° if the partial electron pressure is $1{\cdot}3 \times 10^{-4}$ atmosphere, and pressures of the same order are given by the observed maxima of other lines. A scale of stellar temperatures is deduced. The method of maxima avoids certain difficulties occurring in Saha's original method of appearance points and disappearance points.

Ionisation in the arms of a spiral nebula is discussed by H. Vogt (*A.N.*, **52**, 63).

W. J. Luyten (*P.A.S.P.*, **35**, 175) notes that the D lines are more intense in dwarfs than in giants. W. S. Adams and A. H. Joy find increased intensity for certain low-temperature lines in the spectra of the brighter giant M stars, and observe that the dwarf-giant temperature differences thus continue in the giants themselves (*P.A.S.P.*, **35**, 328).

Wave-lengths.—Accurate measures of wave-lengths of silicon lines occurring in the spectra of B-type stars have been made by H. Barrell (*M.N.*, **83**, 322). New silicon identifications in B-type stars are announced by W. C. Rufus, R. A. Sawyer, and R. F. Paton (*Pop. Astron.*, **31**, 247; *Pub. Obs. Mich.*, **3**, 261).

A list of wave-lengths of lines occurring in spectra of type Me, both absorption and emission, is published by P. W. Merrill (*Astrophys. Journ.*, **58**, 195).

A list of unknown lines in various celestial spectra is given by F. E. Baxandall, *M.N.*, **83**, 166 (revising the Solar Physics Committee Table of 1910). Remarks on o Ceti identifications are added.

Classification.—The Report of the Stellar Classification Committee

of the International Astronomical Union is reprinted in *Astrophys. Journ.*, **57**, 65.

The *Henry Draper Catalogue* has now been published up to 20 hours R.A.

Plates of typical stellar spectra are published by W. C. Rufus (*Pub. Obs. Mich.*, **3**, 257).

In *Astrophys. Journ.*, **56**, 457, P. W. Merrill gives an account of stellar spectra of class S. The memoir contains a table of characteristic lines, typical spectrograms, and a list of 22 S-type stars. It is suggested that the S stars may form a third evolutionary branch, parallel to K–M and to R–N. Later, following a suggestion of F. E. Baxandall, Merrill has identified the bands of zirconium oxide in S-type spectra (*P.A.S.P.*, **35**, 217).

Radial Velocities.—The radial velocities of 1013 stars, chiefly of types F to M, are published by W. S. Adams and A. H. Joy, *Astrophys. Journ.*, **57**, 149; a similar list for 125 stars is published by W. E. Harper, *Pub. Domin. Astrophys. Obs.*, **2**, 189. In *P.A.S.P.*, **35**, 68, W. J. Luyten gives the radial velocities of 4 early-type stars of special interest, and in *P.A.S.P.*, **35**, 171, P. W. Merrill gives a list of 10 stars with velocities exceeding 100 km. sec^{-1}.

An important study of the radial velocities of 133 long-period variables is given by P. W. Merrill in *Astrophys. Journ.*, **58**, 215. The displacement of the bright lines towards the violet, with respect to the absorption lines, is found to increase with advancing spectral type and increasing period. The solar motion from these stars is in the same direction as that usually found for the K and M stars, but the speed is almost three times as much, and the higher-speed stars give still higher values. Some discussion of the general problem of the long-period variables is given.

A study of the radial velocities of the antapex group of stars is given by F. Henroteau, *Pub. Obs. Mich.*, **3**, 39, and one of the radial velocities of the early Potsdam velocity-stars by L. L. Mellor, *Pub. Obs. Mich.*, **3**, 61.

In *Astrophys. Journ.*, **57**, 57, S. Albrecht, in continuation of similar work on oxygen and nitrogen lines, finds a partial explanation of the K-term in the radial velocities of the B-stars in the erroneous wave-lengths previously used for certain silicon lines and a helium blend. The K-term is studied in detail by E. Freundlich and E. v. d. Pahlen (*A.N.*, 5229–30) on the evidence given by J. Voûte's catalogue of radial velocities. They conclude that the effect consists of a constant constituent and a constituent variable with direction in space. The first has probably a physical origin, the second is probably a true kinematic effect. The dynamical implications of the resulting star-motions are considered. The second effect is most marked for the B stars and for the A and F stars of small proper motion, and thus for the most distant stars of the inner galactic system.

Following E. Freundlich and O. Kohl, J. Weber in *A.N.*, 5200, ascribes a 1·1 km. sec^{-1} difference of velocity between the radial velocity of Sirius and the velocity computed from its group-motion to the Einstein displacement.

Spectroscopic Binaries.—The orbits of two dwarfs are given by R. F. Sanford (*Astrophys. Journ.*, **56**, 446); he finds that dwarfs show smaller eccentricities, for given period, than giants, and mean periods much shorter than giants of the same type.

In *Pub. Ottawa Obs.*, **8**, 31, F. Henroteau gives an account of his study of β Canis Majoris, in continuation of earlier work at the Lick Observatory, and comments on the anomalous velocity curves obtained; in *Pub. Ottawa Obs.*, **8**, 45, he gives a study of σ Scorpii; and in *Pub. Ottawa Obs.*, **8**, 61, he gives the result of a search for stars of the β Canis Majoris type among the later spectral classes. The star δ Aquilæ (F) is of this type, with a period of three hours. The writer suggests that such stars represent the disappearing stage of Cepheid variation on the dwarf branch, differing from cluster stars of the same period in being more massive.

T. S. Jacobsen (*P.A.S.P.*, **35**, 229, and *Pop. Astron.*, **31**, 645) has observed the velocity-curves of ζ Geminorum, and compared them with W. W. Campbell's observations of 1898–1900.

Various spectroscopic orbits are given by J. W. Campbell, W. E. Harper, S. L. Boothroyd, J. S. Plaskett, and R. K. Young in *Pub. Dom. Astrophys. Obs.*, **2**, 159, 167, 173, 179, 183, 205; by W. E. Harper, *Pop. Astron.*, **31**, 576, 577; by F. Henroteau, *Pub. Obs. Mich.*, **3**, 39; and by O. Kohl, *A.N.*, 5245. Changes and irregularities in the velocity curves of Cepheids are given by J. C. Duncan (*Pop. Astron.*, **31**, 576) and H. D. Curtis (*Proc. Nat. Acad. Sci.*, **9**, 187).

Special Studies.—Various studies of bright-line B stars are published by R. H. Curtiss, *Pop. Astron.*, **31**, 575; *Pub. Obs. Mich.*, **3**, 1, 16, 256. He finds that it is the brighter B-stars which have a tendency to develop bright lines, and suggests that emission lines are due to the action of resisting media. Stars of this type, with bright lines variable or intermittently bright, are described by W. J. S. Lockyer (ζ Tauri, *M.N.*, **83**, 326), O. Struve (*Astrophys. Journ.*, **58**, 138), and F. Henroteau (θ^2 Orionis, *C.R.*, **176**, 1210). The appearance of bright lines in the spectrum of R Coronæ at minimum is described by A. H. Joy and M. L. Humason (*P.A.S.P.*, **35**, 325). In *P.A.S.P.*, **35**, 145, J. S. Plaskett describes a star with a remarkable variable spectrum; it is of the P Cygni type, but for a month it showed the α Cygni lines; further observations are given by P. W. Merrill, *P.A.S.P.*, **35**, 303. The latter gives two F-stars with H_α bright in *P.A.S.P.*, **35**, 263. A variable with a remarkable spectrum is noted by Miss Cannon, *Harv. Bull.*, 783. In *Harv. Bull.*, 781, she announces a new star of type O. Studies have been made of Algol (I. Barney, *Astron. Journ.*, **35**, 95), of κ Draconis (R. H. Baker, *Pub. Obs. Mich.*, **3**, 29), and of α Canum Venaticorum and R T Aurigæ (C. C. Kiess, *Pub. Obs. Mich.*, **3**, 106, 131).

In *Harv. Bull.*, 789, attention is drawn to ϵ Indi, a dwarf of type K5, spectroscopic parallax $0''\cdot45$, and absolute magnitude $8\cdot0$, which is possibly nearer to the sun than any other naked-eye star except α Centauri.

The radial velocities of the so-called stationary H and K lines in O-type stars have been determined in a number of cases by J. S. Plaskett and compared with the radial velocities of the stars themselves (*M.N.*, **84**, 80). The velocities for the H and K lines agree closely with

the component of the solar motion, differing enormously in some cases from the stellar velocities. The same feature is shown by the H and K absorption lines which occur in the spectra of Wolf-Rayet stars, and it is shared by the D lines. Following a suggestion of H. H. Plaskett, the writer attributes the effects to clouds of calcium vapour (at rest with regard to the main body of the stars), which are ionised in the neighbourhood of very hot stars.

o Ceti. — This long-period variable has attracted considerable attention throughout the year, and the interest culminated when it was discovered to be a double. Work on the spectrum of o Ceti (and three other long-period variables), done chiefly prior to 1917, is published by E. B. Frost and Miss Lowater in *Astrophys. Journ.*, **58**, 265; they found the bright lines displaced some 20 kms. sec.$^{-1}$ to the violet of the absorption lines, but the heads of the titanium oxide flutings gave velocities agreeing with the hydrogen emission; in agreement with previous observers, they found the radial velocity to be constant. Outbursts of hydrogen are suggested as the cause of the phenomena observed. In *P.A.S.P.*, **35**, 168, W. S. Adams and A. H. Joy give some identifications of o Ceti lines with low-temperature lines of iron, silicon, and magnesium. The same subject is discussed by F. E. Baxandall (*Observatory*, **46**, 82), who gives a table of the bright lines. Emphasising the criteria for identification, he suggested that the identification of λ3905 with a silicon line would be confirmed if the weaker companion λ4103 could be detected. In *Observatory*, **46**, 226, he quotes a letter from E. B. Frost and Miss Lowater recording their detection of the latter line some years ago (now published, *v. supra*).

Meanwhile A. H. Joy was coming to the conclusion that o Ceti must be a double. At minimum he noted the coming into prominence of an apparently early-type spectrum, showing bright hydrogen and helium lines, and he observed further (1922) that this bright-line spectrum had a sideways displacement, with respect to the dark-line spectrum, along the length of the slit (*Pop. Astron.*, **31**, 237; *P.A.S.P.*, **35**, 323); from this he was able to estimate a position angle for the hypothetical companion. Further, studying his radial velocity measures he found a velocity curve from the dark lines of the same form as the light curve, with maximum velocity of recession at the maximum of light. At minimum, the bright lines gave the same velocity as the dark lines, and the velocity changes repeated themselves more consistently than the light changes (*Pop. Astron.*, **31**, 645). At Joy's request, the star was observed visually by R. G. Aitken, and on 1923 October 19, the latter saw it as a double, the separation being about 1″ and the companion being of a bluish colour, about half a magnitude fainter than the primary, near the position-angle predicted by Joy (*Harv. Bull.*, 792; *P.A.S.P.*, **35**, 323). Examination in 1903 and 1905 (near minimum) had shown no companion. Aitken observes that this discovery affects the interpretation of all phenomena hitherto observed in o Ceti near minimum.

Statistical Investigations.—The spectra of visual double stars have been exhaustively studied by F. C. Leonard, *L.O.B.*, 343. The difference

in type between the spectra of components is found to be in agreement with Russell's theory of evolution, the less massive stars evolving more rapidly. The results can be applied to deduce parallaxes and projected linear separations of visual doubles for which complete information about both spectra is available (*Pop. Astron.*, **31**, 649).

In a remarkable investigation, K. Lundmark and W. J. Luyten consider the relation between absolute magnitude and spectral type deduced solely from observations of double stars (*Astron. Journ.*, **35**, 93). The ratio of the difference in magnitude of the components to the difference in type shows a frequency distribution with a double maximum. Analysis of this yields a Russell diagram, in which the only uncertainty is the zero of the magnitude scale. This is fixed from consideration of spectroscopic orbits, interferometer observations, and group motions, without any appeal to trigonometric parallaxes, and the results are found to be in good agreement with the usually accepted values.

Determinations of absolute magnitudes for various spectral types are given by J. H. Moore (*P.A.S.P.*, **35**, 124), W. J. Luyten (*P.A.S.P.*, **35**, 209; *L.O.B.*, **344**, 345; *Proc. Nat. Acad. Sci.*, **9**, 317), and R. E. Wilson (*Astron. Journ.*, **34**, 183; **35**, 125). The velocity-distribution of the A-type stars is investigated by G. Strömberg (*Astrophys. Journ.*, **57**, 77). Statistical investigations of the distributions of the various types of stars in space have been made by H. Shapley (*Harv. Circ.*, 245, 248; *Harv. Bull.*, 792).

Theoretical.—A memoir on the escape of molecules from an atmosphere, with special reference to stellar atmospheres, has been published by E. A. Milne (*Camb. Phil. Trans.*, **22**, 483), and another on the same subject by J. E. Jones (*Camb. Phil. Trans.*, **22**, 535).

A theoretical calculation of the value of the stellar absorption-coefficient (of which the observed value is shown by E. A. Milne to be largely independent of the effects of rotation, *M.N.*, **83**, 118) has been given by A. S. Eddington, and applied to revise the theory of dwarf stars (*M.N.*, **83**, 32, 98). Criticisms are made by F. A. Lindemann (*M.N.*, **83**, 332), and replied to by Eddington in *M.N.*, **83**, 431. Calculations of monochromatic absorption-coefficients, with application to stellar atmospheres and stellar interiors, are made by E. A. Milne (*Phil. Mag.*, **47**, 209). E. A. M.

Double Stars.

Measures and New Pairs.—G. Abetti in *Publications of the Observatory of Arcetri* (Florence) has given the measures of about 50 pairs of stars, some under 5″ and some over 5′.

R. G. Aitken in *L.O.B.*, 348, gives the measures of a selected list of double stars (not discovered by himself), made in the years 1913–1922 with the 36-inch refractor. There are in all 1368 observations of 326 double stars. These stars are for the most part well known and approximately one-half are in comparatively rapid orbital motion. Orbits are available for 69 of them and the observations are compared with the ephemerides. Aitken has also measured o Ceti as a double star

(*P.A.S.P.*, **35**, 323), following a suggestion from A. H. Joy that it might be double.

W. O. Beale (*A.J.*, 823) has measured about 150 double stars with the 10½-inch refractor of the Minnesota Observatory. A large proportion of these stars were discovered by Burnham with his 6-inch refractor.

G. C. Comstock in *Publications of the Washburn Observatory*, **14**, part 1, has published his measures of 641 proper motion stars. The proper motions of the stars have been computed. About half of the comparison stars are in Boss's Catalogue, and for the others proper motions have been computed from meridian observations. By means of these, the proper motions of the faint stars (8th to 13th magnitude) have been made absolute. These proper motions are discussed and the direction of the solar apex found to be R.A. 293° Dec. +57°. The high declination of the solar apex found agrees with values previously found from faint stars. Determinations of parallax and radial velocity may be brought into agreement with the results obtained by assuming a progressive increase of linear velocity with diminishing brightness or with increasing distance from the sun.

T. E. Espin in *M.N.*, **83**, 154, gives the results of another year's work by himself and Mr. Milburn. The measures include the new stars Es 1934–2006, for 48 of which the separation is under 5″, and Milburn 242–275, for 27 of which the separation is under 5″. There are a few others unnumbered. The stars are faint and about one-third do not occur in the B.D. The paper also includes measures of 44 known pairs mostly on two nights.

C. P. Olivier (*A.J.*, 818 and 819) gives a complete list of the 110 double stars, with separation under 5″, discovered by him in 1906–1922. They are mostly faint, only 44 being in the B.D. or C.P.D.

T. E. R. Phillips (*M.N.*, **84**, 99) has measured about 60 well-known double stars.

W. Rabe (*A.N.*, **217**, 413) gives the results of his measures of double stars with the 8-inch Clark-Repsold refractor of Breslau. There are 2504 observations of 384 double stars, mostly Σ, OΣ, and β.

K. Schmidt (*A.N.*, **218**, 27) with the same instrument has measured 30 double stars, mostly Σ.

W. H. Van den Bos (*B.A.N.*, No. 34) gives the results of measures of 67 double stars on photographs taken by Luyten with the 33-cm. photographic refractor at Leiden. The separation of most pairs is under 10″, a few distances under 3″ are subject to considerable errors.

C. Wirtz was employed before the war on measuring double stars with the 49-cm. refractor at Strassburg. His measures up to 1910 were published in the Observatory *Annals*, **4**, part 2. His observations, 1910–1914, have been published in the *Annals*, **5**, part 2 (issued from Leipzig). There are over 2000 observations of 777 double stars, and about half were made with a reversion prism. The observations are carefully discussed for personal errors. The measures have been compared with those of well-known observers for "fixed" pairs, while they have been compared with an ephemeris for those stars having elliptical or linear elements. The relation between the difference in the brightness and colour of the components is also discussed.

Interferometer Measures.—A year ago we reported measures of double stars made by Merrill with the 20-foot interferometer of the 100-inch reflector at Mount Wilson. We understand that the interferometer is to be applied to double-star observations at several observatories—Lick, Yerkes, Paris, Strasbourg, Catania. The interferometer attached to the 12-inch refractor of Catania is described by M. Maggini in No. 4 of the Observatory *Contributions*, and the measures of 38 systems with separation varying from 0″·17 to 0″·66 are given in *Reale Accad. Naz. dei Lincei* for July 1923. The measures appear to be excellent.

Orbit Determination.—Orbits of double stars have been published as follows:—

β. G.C.	Name.	Period Years.	*a*.	*e*.	Publication.	Computer.
			″			
270	A 111 AB.	10·5	0·18	0·40	*P.A.S.P.*, 35, 258	Aitken.
1761	Σ 412	270·	0·49	0·55	*L.O.B.*, 348	,,
2187	β 1185	28·9	0·25	0·20	*L.O.B.*, 348	,,
2383	β 552	86·0	0·56	0·51	*L.O.B.*, 348	,,
3291	β 895	45·7	0·26	0·88	*B.A.N.*, 45	Van den Bos.
5805	Σ 2341	84·7	0·35	0·42	*A.N.*, 219, 227	C. M. Riechert.
5951	β 794	63·1	0·34	0·41	*L.O.B.*, 348	Aitken.
6711	β 1270	38·1	0·21	0·41	*L.O.B.*, 348	,,
6913	A 570	28·4	0·20	0·17	*P.A.S.P.*, 35, 221	J. M. Young.
8353	OΣ 341	19·8	0·30	0·96	*L.O.B.*, 348	Aitken.
9979	OΣ 400	84·4	0·43	0·48	*A.N.*, 219, 231	P. Meier.
12404	β 1266	40·	0·22	0·33	*L.O.B.*, 348	Aitken.
13364	Hu. 1176	15·5	0·16	0·14	*P.A.S.P.*, 35, 70 *L.O.B.*, 348	,,
9h 40	ψ Argus	29·9	1·01	0·37	*B.A.N.*, 45	Van den Bos.
17h 31	Russell 297	100·9	3·00	0·17	*B.A.N.*, 45	,,

It will be noticed that there are two new Aitken stars (making 4 for which orbits have been computed) and one Hussey star in the list, and that with the exception of the two far southern stars the semi-major axis is in all cases under 0″·5. There are only two known visual double stars with a shorter period than A 111 AB. Short ephemerides are given with the orbits.

Hypothetical Parallaxes and Masses.—Further attention has been given to the calculation of hypothetical parallaxes and masses. J. Jackson (*M.N.*, 83, 436) has discussed all the OΣ stars and calculated hypothetical parallaxes for 132 showing relative motion, and (*M.N.*, 83, 441) he has calculated hypothetical parallaxes for the 126 Aitken and 37 Hussey stars for which published observations show considerable relative motion. The hypothetical parallaxes of 154 Aitken double stars have also been computed by Aitken and Miss Powell and communicated to the American Astronomical Society

(*P.A.*, **31**, 575). Russell announces (*P.A.*, **31**, 250) that a card catalogue of 1600 hypothetical parallaxes has been prepared at Princeton, and (*P.A.S.P.*, **35**, 189) in collaboration with W. S. Adams and A. H. Joy, he compares spectroscopic and dynamical parallaxes. There are 327 stars for which both parallaxes are available, and the mean masses of stars of the different spectral types (dwarf and giant) are deduced. The largest mean mass is 6·2 times that of the sun for type O8 – B2 and the smallest 0·6 for dwarfs of types A and F. The mean mass is not found to be a simple function of the spectral type. When masses were plotted against the absolute magnitudes, all the stars—including red giants and white dwarfs—fell into line, so that (statistically considered) the mass of double stars may be considered as a function of the absolute magnitude rather than the spectral type. Jackson (*M.N.*, **83**, 444), from a consideration of the proper motions and hypothetical parallaxes, determined the mean masses of binaries according to spectral type and found the mean masses of the early type stars relatively large.

G. Abetti has determined the relative masses of the components of α Coronæ and found the fainter 2·6 times as massive as the brighter (*Reale Accad. Naz. dei Lincei*, 1922 June). He has also determined the sum of the masses and the ratio of the masses of spectroscopic double stars (*ibid.* 1922 September) as follows :—

Mean Type.	No.	m_1+m_2.	m_2/m_1.
B 2	27	9·7	0·52
A 1	37	6·9	0·47
G 6 giants	18	3·3	0·78
F 9 dwarfs	22	1·4	0·65

Miscellaneous.—A detailed examination of the spectra of the separate components of 238 double stars has been made by Mr. F. C. Leonard (*L.O.B.*, 343). A considerable number of well-known binaries are included, and many of them have a separation under 5″ and a few under 2″. The principal conclusion, previously announced by several writers from less material, is that the spectrum of the secondary component is generally of "later" class than that of the primary in dwarf systems, but of "earlier" class in giant systems. The difference in the spectra increases in general with the difference in magnitude. The results fit well into the Russell scheme of stellar development. Mr. Leonard has applied his results in a paper to the American Astronomical Society (see *P.A.S.P.*, **35**, 265, or *P.A.*, **31**, 649). In this paper he has computed the parallaxes of 153 double stars for which no acceptable parallaxes were known, and checked his results by 85 double stars of known parallax. The same subject has been treated by Mr. Doig in several papers to the *B.A.A. Journal*, in one of which he computed the "spectral" parallaxes of 62 connected pairs (*B.A.A.J.*, 33, 195). Lundmark and Luyten (*A.J.*, 828) have derived a scheme corresponding to the giant and dwarf classification from a consideration of the absolute magnitude and spectral classes of double stars. The colour indices of both components of 35 double stars have been determined by G. Abetti (*Arcetri Observatory Publications*).

The luminosity-curve of the components of double stars has been discussed by E. Öpik (*Tortu Observatory Publications*, **25**, No. 5): in this treatment 645 close pairs and 121 wide pairs were considered. P. W. Merrill (*A.P.J.*, **57**, 251) has given the results of spectroscopic observations of the variable double star X Ophiuchi, and Otto Struve (*A.P.J.*, **58**, 141) has discussed the binary star 9 Argus, deducing the relative mass of the components from spectroscopic observations. J. J.

Variable Stars.

The amount of observational and statistical work on variable stars published annually is steadily increasing, and it is becoming more and more difficult to give in a few pages an adequate summary of even the more important results achieved in this department of research.

Among the more outstanding features of the work done in 1923 may be mentioned P. W. Merrill's detailed and statistical study of the radial velocities of a number of long-period variables, and R. G. Aitken's discovery of the duplicity of Mira Ceti. Both of these will be referred to in detail later.

As usual, a very large number of individual observations, chiefly of long-period variables, have been published throughout the year in *P.A.*, *Ast. Nach.*, and elsewhere, and these are available to those desiring to study the light curves of the objects concerned. Lists of new variables will be found in *H.C.O. Bulletins*, 779, 781, 783, 786, 790, 791, and 792. The notes which follow refer chiefly to special studies of variables presenting interesting or unusual features, and to certain statistical investigations.

Short-Period Variables.—In *Ap. J.*, **57**, 1, J. Stebbins gives the results of photo-electric observations of *b* Persei. The light curve shows it to be an ellipsoidal variable, with a total range of $0^m{\cdot}06$. Of this $0^m{\cdot}05$ is due to the ellipsoidal figures of the components, the residue being possibly a periastron effect. If any eclipse occurs it must be very slight. The spectrum is A2 and the period $1^d{\cdot}52732$.

In *Ap. J.*, **57**, 129, G. Shajn discusses the effects on the light curves of eclipsing variables produced by regression of the line of nodes (due to oblateness of the stars involved).

In *Ap. J.*, **58**, 75, Ch'ing-Sung Yü finds from a study of the photographic light curve of CG Cygni, discovered by A. Stanley Williams in 1905, that the star is an eclipsing variable of the Algol type. The larger and fainter component is of later spectral type than the other, and there is evidence of ellipticity of figure and darkening at the limbs of both stars. There is a slight increase in the total light when the brighter component is approaching in the line of sight.

In *Ap. J.*, **58**, 164, R. S. Dugan discusses the light curves of the eclipsing variables SZ Herculis and RS Vulpeculæ. In the former the eclipse is nearly total. The observations are best satisfied in both cases by assuming uniformly illuminated discs.

In *Publ. Ast. Soc. Pac.*, **35**, 255, T. S. Jacobsen gives measures of

the radial velocity of ζ Geminorum. These yield a period shorter than the accepted visual one by a quantity of the order of $0^{d}\cdot0015$.

In *Ast. Nach.*, 5253, F. Henroteau and J. F. Fredette give photometric observations of B.D. $+46^{\circ}2731$ (mag. 7·9), which they find to be a variable of period $28^{d}\cdot5 \pm$ and range $0^{m}\cdot2$. The star is of early type (B or A), and the suggestion is made that it may be a rotating ellipsoidal variable.

In *Ast. Nach.*, 5260, H. Fuss gives determinations of the parallax and proper motion of the Cepheid variable RR Lyræ. He finds for the parallax a value of $+0''\cdot0003$ ($\pm 0''\cdot0038$), and recalls that Van Maanen found it to be $+0''\cdot006$ ($\pm 0''\cdot006$). He concludes that it is certainly not greater than $0''\cdot01$. For the proper motion he finds $-0^{s}\cdot0110$ and $-0''\cdot187$ in R.A. and Dec. respectively.

In *H.C.O. Bulletin* 791, it is stated that a faint star in Libra, previously noted by Comas Sola as a possible nova, is shown by examination of Harvard plates to be a short-period variable with very sharp maximum. Period $0^{d}\cdot369$. In the same bulletin are also given the elements and light curve of the eclipsing variable SX Hydræ. The range (4 magnitudes) is unusually great and the eclipse is apparently total. There is no indication of ellipticity and no secondary minimum.

In *Journal B.A.A.*, 33, 28, E. E. Markwick discusses the light curves of six Cepheids, including δ Cephei, constructed from observations by himself and M. Moye. In *L'Astronomie* for 1923 August, A. Danjon discusses the light curve of δ Cephei as determined from the early observations (from 1784) and those made more recently. He concludes that the period has suffered a secular diminution, amounting in all to about 20^{s} since the discovery of the star's variability.

In *Journal B.A.A.*, 33, 279, E. E. Markwick presents a study of the light curves and periods of three short-period variables (β Lyræ, *u* Herculis, and RT Aurigæ), as deduced from observations by the Variable Star Section of the Association. A slow increase in the period of β Lyræ is brought out, and there is some evidence of a similar increase in the case of *u* Herculis, but it was found impossible to construct a smooth curve for this latter star.

Long-Period Variables.—In *Ap. J.*, 57, 251, P. W. Merrill gives the result of an investigation of the parallax and absolute magnitude of the long-period variable X Ophiuchi (type M6e, period 337^{d}). The star is a close binary, and a study of the spectrum of the K-type companion gives a parallax of $0''\cdot005$. From this value the absolute magnitude of the variable primary at maximum is found to be $0^{m}\cdot3$.

Ap. J., 58, 215, contains a very valuable statistical discussion, by the same author, of the radial velocities of 112 long-period variables determined at Mount Wilson since 1919. The discussion reveals two additions to the previously established correlations of advancing spectral type, increasing period, and increasing range. These are increasing displacement of bright relative to dark lines, and decreasing random velocity. In the case of four stars there is evidence of a slight variation in the negative displacement of the bright lines with phase. An increase appears to occur towards the time of maximum, attaining its highest value a month or so after this phase, and then returning to normal.

In *Publ. Ast. Soc. Pac.*, **35**, 168, W. S. Adams and A. H. Joy announce that, in the spectrum of *o* Ceti when fading, they have identified among the narrow bright lines several low-temperature radiations of iron, magnesium, and silicon. On p. 171 of the same number, P. W. Merrill gives measurements of the radial velocities of ten long-period variables. In every case the velocities obtained from the absorption lines are algebraically greater than those given by the bright lines. He believes that the former should be taken as representing the true radial motion of each star as a whole.

In *Publ. Ast. Soc. Pac.*, **35**, 323, R. G. Aitken announces his detection, with the 36-inch Lick refractor, of a close companion to Mira Ceti. The observation was made on 1923 October 19, at the request of A. H. Joy, who, from a study of the recent spectrum of the variable, had deduced the existence of a *comes* of early type at $\Delta = 0''{\cdot}25 \pm$ and P.A. $135^\circ \pm$. The companion was seen at once by Aitken, whose measures gave $\Delta = 0''{\cdot}90$ and P.A. $130^\circ{\cdot}3$. It appeared to be bluish-white in colour, confirming Joy's deduction, and was of about magnitude 10·0. The magnitude of Mira, then near its minimum, was 9·2. From the repeated failures of himself and others to detect any companion in 1903, 1905, and 1921, Aitken infers a recent and rapid increase of distance. The pair is undoubtedly binary in character, otherwise the considerable annual p.m. of the primary ($0''{\cdot}23$) would have insured the earlier detection of the companion. Aitken points out that the presence of the *comes* involves the necessity of a correction to the light curve, especially near minimum, when it amounts to $0^m{\cdot}5 \pm$. Thus the range of the primary is seen to be actually greater than was supposed.

Leon Campbell contributes several notes on long-period variables to *H.C.O. Circulars* and *Bulletins*. In *Circular* 244, he gives a list of observed maxima and minima of 376 stars during 1922, with a comparison of the O − C values; and in 250 he gives predicted maxima and minima of 369 stars for 1924.

In *Bulletin* 778, he presents the results of a study of 15 long-period variables of class S, as compared with other types. The S stars appear in general to have longer periods and greater range. Also, on the average, their galactic latitudes are lower, which may indicate that their absolute magnitudes are greater. In 781, he shows that the red variable V Hydræ, previously classed as irregular, has a period of 530^d, $\pm 16^d{\cdot}6$. This result is derived from a study of observations, covering the period 1905–23, including 12 maxima and 12 minima. There is some evidence of a secondary minimum. In the same *Bulletin* the results are given of an examination of the observations of W Tauri, made during two periods, viz. 1887–1900 and 1904–23. The two sets of observations give, respectively, periods of 275^d and $266^d{\cdot}5$. The evidence for change is considered conclusive.

In *H.C.O. Bulletin* 783, there is a note on the variables in the globular cluster 47 Toucani. An examination of plates taken at the Harvard station shows that three of the seven known are not Cepheids but long-period variables of period $200^d \pm$, with ranges typical of such stars. They are probably of high absolute magnitude, having regard to the probable parallax of the cluster. In the same *Bulletin* it is

announced that RS Cygni, previously classed as irregular, proves to be a long-period variable. The light curve is of an unusual type, and the range ($1^m.0 \pm$) abnormally small. The period, deduced from a study of observations covering the interval 1902–23, is found to be 413^d.

In *H.C.O. Bulletin* 784, Leon Campbell announces that, from a study of observations of W Persei made between 1893 and 1923, the star, previously considered irregular, is a long-period variable of period 400^d–600^d. A value of 496^d best fits the observations. The range is only $1^m.3$, and the variable has a flat maximum and short minimum. In *Bulletin* 787, the same author finds a period of $155^d.3$ (range $1^m.7$) for X Monocerotis, also previously classed as irregular. The observations extend from 1903–23.

In *M.N.*, 83, 377, E. Prentice analyses harmonically observations of R Vulpeculæ made by Knott and later observers. The analysis confirms Turner's conclusion as to a slight increase of period, but such secular increase is largely masked by variable oscillations of period. In this respect the star resembles T Herculis, previously analysed by Phillips.

In *Journal B.A.A.*, 33, 316, F. de Roy summarises the results of work done in 1921 by the Variable Star Section of the Association, on 27 variables of period greater than 300^d. On p. 326, P. Doig discusses statistically the luminosities and motions of long-period variables.

Irregular Variables.—In *Publ. Ast. Soc. Pac.*, 35, 325, A. H. Joy and M. L. Humason give details of the spectrum of R Coronæ. At the constant phase it is of Cepheid type (Go); but at minimum it contains bright enhanced lines of titanium, displaced towards the violet. The absorption spectrum remains unchanged at all phases.

In *L'Astronomie* for 1923 January, J. du Doré reports that on 1922 November 19, he found the star 77 Aquarii (mag. $6 \pm$) to be brighter than its near neighbour δ Aquarii (mag. 3·5). During the following three or four weeks M. Gazeau observed a slow decrease from 4th to 5th magnitude. On the other hand, F. Quenisset found the star to be of normal brightness on November 21 and December 15. Gazeau noted a strong scintillation, and the star appeared to be pure white.

In *H.C.O. Circular* 247, Leon Campbell and H. Shapley give a light curve of R Coronæ from the date of its discovery (1784) to 1923.

In *H.C.O. Bulletin* 780, it is stated that an examination of Harvard photographs of the variable C.P.D. $-37°.8450$ (involved in the nebula N.G.C. 6727 and observed by Knox-Shaw and others) leads to the conclusion that the variations are irregular. The range observed is from $8^m.6$ to $10^m.5$. The suggestion made by Innes that the star is an Algol variable is not confirmed.

In *H.C.O. Bulletin* 783, it is announced that the star H.D. 81137 (type Ma), of magnitude 10, has a remarkable spectrum with bright lines, resembling that of η Argûs, and that the light of the star undergoes a slow and irregular variation of very long period.

In *M.N.* 83, 515, A. D. Ross and R. D. Thompson give photometric observations of β Ceti made by them in 1923 March. The star had been reported by Abbott of Athens to have been of the 1st magnitude in February. The authors of the paper conclude from their observations that a real brightening had taken place previous to March 1, and believe

that there is some evidence of fluctuations during the subsequently observed fall. The normal magnitude of the star is 2·2.

In *Journal B.A.A.*, 33, 277, C. L. Brook gives the light curve of SS Cygni, constructed from observations made by the Variable Star Section of the Association during 1922.

Novæ.—In *Publ. Ast. Soc. Pac.*, 35, 95, Knut Lundmark gives a very valuable statistical discussion of the data so far available with regard to novæ, making certain suggestions as to their possible mode of origin and their position in the sequence of stellar evolution. On p. 124 M. L. Humason reports the discovery of a 17th magnitude nova in the Andromeda Nebula (M31). The object appears on a photograph taken with the Hooker telescope on 1923 February 15. Its distance from the nucleus of the nebula (1′·5) is less than that of any nova previously observed, with the exception of that of 1885.

In *Publ. Ast. Soc. Pac.*, 35, 145, J. S. Plaskett describes some remarkable variations observed in the photographic spectrum of the star B.D. +5°·1267 (B.D. mag. 7·1). There are normally present bright hydrogen lines with dark companions displaced towards the violet by varying amounts, recalling the spectrum of a nova, or that of P Cygni. Occasionally there are imposed upon this spectrum the typical α Cygni lines of enhanced iron, titanium, and chromium. The entire spectrum varies between Bo and A2. The author of the note appeals for a parallel photometric study of this star in view of the marked variation in the spectrum. The R.A. of the star is erroneously given as $5^h\ 25^m{\cdot}2$. It should be $6^h\ 25^m{\cdot}2$. On p. 166 of the same number, C. O. Lampland announces the photographic discovery, with the 40-inch Lowell reflector, of a 14th magnitude nova near the nucleus of the nebula N.G.C. 5236 (M83). It first appeared on a plate taken 1923 May 5, and was still of the same brightness eleven days later. It is inferred from this that the star was some way past its maximum.

In *Publ. Ast. Soc. Pac.*, 35, 261, E. Hubble gives particulars of the magnitude of Belanowsky's nova in N.G.C. 4486 (M87) as determined from plates taken with the Hooker telescope from 1920 to 1923. The nova, which reached a magnitude of at least 11·5 in 1919, was of magnitude 20 ± in 1920 February and March, but has been below $21^m{\cdot}5$ since 1921. Hence the range was at least 10 magnitudes.

In *H.C.O. Bulletin* 782, the results are given of an examination of Harvard plates covering the field of the faint nova announced by Innes in *Union Obs. Circ.* 37. The light curve of this object proves to be similar to that of Nova Aquilæ III., but with a very extended time scale. Previous to 1916 the magnitude was constant at 16 ±. In 1916 July it was $12^m{\cdot}1$, rising slowly to a maximum of $9^m{\cdot}2$ on 1917 July 17. After that it faded, and had reached $12^m{\cdot}8$ by 1920 September.

In *H.C.O. Circular* 247, Leon Campbell and H. Shapley give light curve of T Coronæ, covering the whole period from its first outburst (1866) to 1923. Since 1870 the magnitude has been practically constant at $10^m{\cdot}0$ ±.

In *H.C.O. Bulletin* 789, is a note to the effect that the star RT Serpentis, which before 1909 was fainter than 16th magnitude, has for thirteen years been brighter than $11^m{\cdot}0$. The remark is made that

"apparently this is the one object in the sky most deserving of the designation 'new star.'"

In *H.C.O. Bulletin* 792, particulars are given of the light curve of VY Pegasi, which appears to have been a nova of exceptionally slow development, like the Innes star mentioned above. It first appeared in 1908, reached a maximum of 11th magnitude in 1920, and then steadily faded. Its magnitude in 1923 July was less than 15·4. K. Graff gives observations of this same object in *Ast. Nach.*, 5245. In 1922 August the magnitude was 11·6, but in 1923 January it was less than 14·7.

In *M.N.*, **83**, 160, W. H. Steavenson gives the results of photometric work on certain Novæ during 1922. Among these are Hind's Nova Ophiuchi (1848) and Nova Cygni (1876), both of which show slight variability. Nova Cygni (1920) was observed to be slowly fading, falling from $10^{m}\cdot3$ in May to $11^{m}\cdot1$ in December. Nova Aquilæ (1918) was practically constant at $10^{m}\cdot0\pm$ during the whole of 1922, having nearly reached its original brightness in a period of less than four years. A note on this nova is to be found in *H.C.O. Bulletin* 781, where the visual magnitude in 1923 is given as 10·1, and the photographic 10·2. It is remarked that through all its changes of light and spectrum the colour-index has only varied between the limits of $+0\cdot2$ and $-0\cdot5$.

In *M.N.*, **83**, 397, W. H. Steavenson gives photometric observations of Nova Persei (1901) made on 101 nights in 1922–23. The observations demonstrate the continuation of the marked variability noted in previous years by Barnard and others. This is apparently of a very irregular character, but there appears to be some slight similarity between the light curve for 1922–23 and that for 1921–22. The maximum brightness observed in 1922–23 was $12^{m}\cdot2$ and the minimum $14^{m}\cdot1$. An appeal is made in the paper for more observations of this nova, which has been much neglected since it became a faint object.

W. H. S.

Nebulæ.

Thirteen years have elapsed since the last Council Note on this branch of astronomy, which from the cosmological standpoint is of primary importance. During that time our knowledge of the constitution of both the galactic (gaseous and diffuse) nebulæ and those of the spiral class has been very greatly extended. It is only necessary to cite on the theoretical side J. H. Jeans' researches in his "Problems of Cosmogony" and other papers, and on the observational side the work of Van Maanen, Shapley, Hubble, and Duncan at the Mt. Wilson Observatory, the issue in 1918 of *L.O. Pub.*, 13, and the extension of our knowledge of the southern nebulæ at the Helwân Observatory, in confirmation of the great advances made in recent years. In the gaseous nebulæ the important work of physicists at Cambridge and elsewhere on the constitution of the atom, and the compilation of the scale of atomic numbers, coupled with the correlation of spectral types with temperature, has given us an entirely new conception of the nature of these formations, which undoubtedly depend for their development on the temperature and resulting physical conditions of stars involved in the nebulæ. The

unidentified radiations appearing in the spectra of the gaseous class may now in general be ascribed probably to ionisation of the lighter gases, but there seems to be another source of radiation, at present unknown, although it is evident that this source must be some physical condition in connection with known elements. The principal work done on the galactic nebulæ during the last year or so has been that of Hubble at Mt. Wilson (referred to briefly in the 1922 Annual Report). In *Mt. Wilson Cont.*, 241, he suggests a classification of the galactic and non-galactic nebulæ which forms a suitable basis for discussion. Its principal new feature is the recognition of a class of small non-galactic nebulæ which show no spiral form, and are in all probability to be regarded as nuclei from which no spiral arms have been developed. This is a class to which attention was specially drawn by Knox Shaw in *Helwân Bulletin* 15 in 1915. Hubble deals in this paper first with the spectra of the diffuse nebulæ. Of these, 33 were found by him to give a continuous spectrum, while 29 gave an emission spectrum, superimposed on a continuous spectrum of various degrees of brightness. A study of the spectral types of the stars involved in diffuse nebulosity shows that those connected with "continuous" nebulæ are of later types than those involved in "emission" nebulæ. In the "continuous" nebulæ only B type and later appear, the average being B4. On the other hand, the "emission" nebulæ contain stars as early as O*e*5, and none are later than Bo. The natural conclusion drawn is that this type of nebulosity depends on the spectral type (and therefore temperature) of the involved stars, the continuous spectrum being in all probability reflected starlight, and the emission spectra being produced by physical conditions associated with the hotter stars. The trend of opinion amongst some workers in nebular astronomy has been in this direction for some years past, but it has been left to Hubble to demonstrate its validity in a number of instances sufficient for the result to be regarded as general. In a later paper (*Mt. Wilson Cont.*, 250) Hubble discusses "The Source of Luminosity in Galactic Nebulæ." If, as seems probable, nebulæ reflect or re-emit the light of the involved stars, the angular size of the nebulæ will depend on the brightness of the stars which are assumed to be undimmed by absorption. In accordance with the inverse square law, the square of the maximum angular extent of nebulosity a, for an exposure E, should be proportional to E times the apparent luminosity of the star I, or $a^2/\mathrm{E} = a^2_1/60 = \mathrm{I} \times \text{Constant}$, or $m + 5 \log a_1 = \mathrm{B}$, where a_1 is the angular distance reduced to a uniform exposure of 60 minutes. For Seed 30 plates and a focal ratio of 5 to 1, B = 11·6 or 10·6 according as the line joining the star to the faint nebulosity is perpendicular to the line of sight or has the mean inclination corresponding to random direction. To test this equation, data for 82 nebulæ were plotted, $\log a_1$ against m. The points lie near the line: $m + 4{\cdot}9 \log a_1 = 11$, thus showing that the inverse square law holds closely and that the other assumptions are approximately correct. The law holds good also in cases of emission spectra as well as continuous spectra, so that the luminosity must be due to re-emission of the same actual actinic value in such cases. He applies the same method to the planetary nebulæ, but for these objects the agreement is not nearly so close,

the observed luminosity per unit area being about four times brighter than the theoretical.

In the case of the spiral nebulæ, the outstanding contribution has been the measurements by Van Maanen of the motion of condensations in the spiral arms, *Mt. Wilson Cont.*, 242, 243, and 260. This work now includes the following spirals: M. 101, 33, 51, 81, 63, 94, and N.G.C. 2403, the measurements being made on plates exposed at intervals varying from 8 to 12 years with the 60-inch reflector. The proper motions of the spirals in general come out small, while the evidence is in favour of motion of the condensations outward along the streamers of the spirals combined with an outward transverse motion, with a considerable increase in velocities with distance from the nucleus. Van Maanen also discusses the question of the parallaxes of the spiral nebulæ, and concludes that the most reliable methods are (1) Jeans' method of the formation of the condensations in the spiral filaments, (2) comparison of proper motions and radial velocities, and (3) comparison of internal proper motions and spectroscopic velocities. These methods combine in indicating probable parallaxes of 0″·0001 to 0″·001, corresponding to distances and actual dimensions much less than would be required on the island universe hypothesis. Jeans has dealt with the theoretical aspect of these results in his "Problems of Cosmogony," and more recently in *M.N.*, 84, 60. He points out in the latter that the acceleration of the condensations in the outer regions of the nebulæ cannot be explained either by ordinary gravitation, gas pressure, viscosity, radiation pressure, or electro-magnetic forces, and the only course open seems to be to assume that the gravitational field is modified in such a way that conservation of energy and of angular momentum both disappear. Spectroscopic observations have shown in the case of the Andromeda and other spirals that the nuclei rotate practically as if they were solid bodies, and the same seems to apply to the spiral arms as well in combination with the outward motion. Another paper by J. H. Jeans, entitled "The Mechanism and Structure of Planetary Nebulæ," appears in *M.N.*, 83, 481. It is now generally recognised that the so-called Ring and Planetary Nebulæ consist of gaseous shells surrounding a star of high temperature, usually O type. Such shells cannot be explained as masses of gas in equilibrium under gravitation and rotation. Radiation pressure has often been suggested as a probable cause of the observed forms, and Jeans in this paper examines to what extent planetary nebular forms can be explained as the result of joint action of gravitation, rotation, and radiation pressure of a central star. A great difficulty in this inquiry is the relation of the actual radiation energy to the mass of the central star. Van Maanen in the case of six planetaries finds the value of E to be only one-fortieth of that of the sun, while on the assumption that the spheroidal form of the nebulæ results from a balance between gravitation and rotation, a combination of the spectroscopic velocities of rotation with the linear dimensions calculated from Van Maanen's parallactic determinations leads to values of M varying from five to fifty times that of the sun. The explanation of this great discrepancy is probably to be found in the relatively low actinic energy of the light actually reaching us, on

which the absolute magnitudes are based in the case of the nuclear stars. The ultra violet intensity is twice as great at λ3400 as at λ4000, and the maximum intensity is probably far in the ultra violet beyond the limit imposed by the earth's atmosphere. Taking this into account and treating the radiation as mainly ultra violet, Jeans arrives at certain theoretical cross sections for the gaseous shells, and quotes examples of the planetaries which bear a general resemblance to these. He points out that a great difficulty is introduced by the observed irregular figures of some of the planetaries, as the agencies considered in the paper can only give rise to figures symmetrical about the axis of rotation. But apart from this, no widening of the fundamental hypothesis of the paper will account for the large number of planetaries whose main visual feature consists of two surfaces both flattened out in the direction perpendicular to the axis of rotation. The general results of this important paper are to some extent, therefore, inconclusive.

F. A. Lindemann (*M.N.*, **83**, 354) has propounded a theory of the origin of spiral nebulæ based on the expulsion of finely divided matter from the galactic plane by the integrated radiation pressure of the galactic stars, thus accounting for the large positive radial velocities usually observed. It was found some years ago that the outer regions of spirals were photographically deficient in the longer wave-lengths compared with the nuclei, and this has led Lindemann to put forward the hypothesis that the spirals are visible by reflected light from the Galaxy. The latter part of the hypothesis was criticised by J. H. Reynolds (*M.N.*, **83**, 382), while on the theoretical side letters appeared in *Nature* by J. H. Jeans and Sir Oliver Lodge. The work on the galactic distribution of the non-galactic nebulæ of the spiral class inaugurated by A. R. Hinks and J. A. Hardcastle in 1911 and 1914 has been continued and elaborated by J. H. Reynolds (*M.N.*, **82** and **83**) on material given by the *L.O. Pub.*, **13**, the *Helwân Bulletins*, the *Mt. Wilson Cont.*, and the Franklin Adams plates. The small scale of the latter, and the great optical distortion at the corners of the large plates used, does not in many cases give reliable evidence as to the type or dimensions of nebulæ of this class, and advantage has been taken of the larger scale material now available to group the spirals according to angular dimensions and the inclinations of their planes with the line of sight. It is found that the larger spirals appear in the galactic hemisphere, of which the pole is $\lambda = 140^\circ$ $\beta = 0^\circ$, the star clusters lying almost entirely in the other hemisphere. Although no regular distribution of position angles of the spiral planes with regard to the plane of the Galaxy has been detected, a relation between angular dimensions and the inclination of the spiral planes to the line of sight is indicated from the material discussed. The meaning of this result is not clear, and there may be some systematic effect which would produce it. At the same time, the photographs themselves yield no evidence as to the nature of such a systematic effect.

J. C. Duncan continues the study of forms and structure of nebulæ in *Mt. Wilson Cont.*, 256, especially of areas of dark nebulosity in the Galaxy, of which some beautiful photographs are reproduced.

J. H. R.

Meridian Astronomy.

Fundamental Catalogues.—In the Council Report for 1915, attention was drawn to the periodic correction in Right Ascension required by the fundamental Catalogues of Auwers and Boss. The same question has been considered by Roy, who has made comparisons with a number of catalogues which have been published since the Preliminary General Catalogue. Though these do not accord together so well as could be wished, they indicate unmistakably a periodic correction in right ascension. They are confirmed by the second Cape Catalogue for 1900 (1912–1916) and the Greenwich Catalogue for 1925 (unpublished), and by the comparison of Washington with Newcomb.

	s	s	s
1912–16 Cape-Boss	$+ \cdot 012 \cos a$	$- \cdot 013 \sin a$	$+ \cdot 007 \cos 2a$
1915–21 Greenwich-Boss	$+ \cdot 006 \cos a$	$- \cdot 006 \sin a$	$+ \cdot 002 \cos 2a$
1911–18 Washington-Newcomb	$+ \cdot 009 \cos a$	$- \cdot 010 \sin a$	$+ \cdot 004 \cos 2a$
		$+ \cdot 002 \sin 2a$	

Recent observations of the Sun agree in indicating a correction to the Equinox. Some recent values are:—

		s
Washington	1903–1911	−0·052
Cape	1907–1911	− ·064
Greenwich	1906–1914	− ·045
Cape	1912–1916	− ·048
Greenwich	1915–1921	− ·069

At the Cape Observatory, Mr. Hough discussed the observations of Mercury and Venus, and obtained $-0^s \cdot 046 - 0^s \cdot 044$, in good accordance with the value $-0^s \cdot 053$ given by the Sun. It is to be borne in mind that the determination of the correction for Equinox is one of great difficulty and uncertainty, as any personal equation in observations of the Sun relative to the Stars enters with its full amount. The introduction of the impersonal micrometer at Greenwich numerically increased this quantity by $0^s \cdot 03$ (see Cullen, *M.N.*, 81, 423), and it is possible that a similar result has been produced in other observatories.

Recent catalogues also suggest that the right ascensions of the Preliminary General Catalogue are too great for stars of high north declination.

As regards declinations, the Cape Catalogue 1912–1916 gives corrections less than $0'' \cdot 2$ from $+35^\circ$ to the South Pole. The Pulkovo Catalogue by Bonsdorff gives even smaller corrections from -10° declination to the North Pole. The Greenwich Catalogue gives a correction of about $+0'' \cdot 2$ from -20° to $+50^\circ$, and is in agreement with Boss for higher declinations. Judging from the figures given in the *American Ephemeris* for 1925, Boss's Catalogue requires a correction of nearly $+0'' \cdot 5$ for the epoch 1925. From the reports to the Carnegie Institution it appears that the San Luis zenith distances have been completely reduced, and exhaustive discussions made as to the latitudes and the refractions. In *Popular Astronomy*, 1924 January, Mr. Varnum

states that investigations he has made disclose very systematic errors of Boss's Catalogue, that of the form $\Delta\delta_8$ being particularly large. He finds a correction of $+''\cdot0043$ annually to the declination proper motions near declination $+39°$. This will bring Boss's system into closer accord with that of Auwers. It will also give a lower declination for the position of the Solar Apex. It does not, however, nearly reach the amount $+''\cdot0136 \cos\delta$ which Kapteyn considered necessary to bring the position of the Solar Apex derived from proper motions into harmony with that from the radial velocities.

It seems possible, though different catalogues are not unanimous, that a small periodic correction is required by Boss's declinations, in the sense of increasing those at about 18^h relatively to those at 6^h.

Attention may be drawn to a recent publication of the Cape Observatory giving the positions of 99 Southern Circumpolar Stars extending from $-77°\ 30'$ to $-90°$. Photographic and heliometer observations have been combined with those made with meridian instruments. All available material has been used in the determination of proper motions. This catalogue will be very valuable for meridian work in the Southern Hemisphere.

Backlund-Hough Stars.—In connection with the re-observation of reference stars for the Astrographic Catalogue, a list of 3064 stars compiled by Backlund and Hough was proposed for fundamental observations by co-operating observatories. About two-thirds of these stars are found in Boss's Catalogue, and the remainder were chosen in parts of the sky where none of these stars occur, in order to obtain a uniform distribution of fundamental stars over the whole sky. At the Cape Observatory 16 observations of each star, four in each position of the instrument, form the basis of two fundamental catalogues of great value. At Pulkovo a catalogue of fundamental observations by Bonsdorff for 1925·0 extends from the pole to declination $-10°$, and is of the high accuracy associated with Pulkovo. At Paris the catalogue is completed and is in the hands of the printers, while the catalogues at Washington and Greenwich are completed and nearing publication.

The proper motions of many of the Backlund-Hough stars have been determined by Nyrén, and are published in the Memoirs of the Academy of Sciences of Stockholm. This valuable work adds considerably to the number of stars whose proper motions have been accurately determined. These proper motions are reduced to the revised system of Auwers.

Cincinnati Catalogues.—In 1922 a catalogue of 4683 stars was published by the University of Cincinnati. As is well known Dr. Porter has been engaged for many years in the re-observation of stars known to have considerable proper motion. He has used the Cincinnati observations with all earlier observations to determine the proper motions of these stars as accurately as possible. The details of the determinations, reduced to Auwers's system, are published in separate volumes. This work is of interest to those engaged in parallax or spectroscopic work, as it collects together those stars which, from their proper motions, are presumably near.

Intermediary Stars.—In addition to the fundamental stars, it was considered, at the Paris Astrographic Conference of 1909, that a series of "intermediate" stars consisting of four to six stars per hour in each zone of 2° wide of magnitudes $8^{m}\cdot0$ to $9^{m}\cdot0$ would serve a valuable purpose in co-ordinating zone observations of reference stars. These intermediary stars have been observed at a number of observatories, though little has yet been published. The large section from +90° to −30° has been completed at Washington; from +15° to −15° at Paris; from +15° to −10° at Nice; from +50° to +55° at Königsberg. In the Southern Hemisphere the zone −51° to −65° has been observed at Sydney and a catalogue published. This observatory is now engaged on the zone −30° to −51°.

The intermediary stars derive additional interest from the proposal of Professor Schlesinger to use them as reference stars on large plates taken with a wide-angle doublet, and thus to observe photographically the stars of the *Astronomische Gesellschaft*, and other stars chosen as reference stars for the smaller plates of the *Astrographic Catalogue.*

Zone Catalogues.—In recent catalogues at Greenwich, Berlin, and Christiania, the part of the sky round the North Pole has been well surveyed and proper motions of many stars derived by comparison with earlier catalogues. No catalogues have been published recently for the region +64° to +40°. A catalogue of 8803 stars from +40° to +31°, chosen as reference stars for the Potsdam Astrographic Zone, has been published by the Babelsberg Observatory. The mean epoch of observation is near 1920, and proper motions of most of the stars have been determined by comparison with earlier catalogues. A catalogue of stars for the zone +24° to +32° has been made from Greenwich observations about the epoch 1910, and proper motions have been deduced. The zone +25° to +18°, containing 14,263 stars, has been observed at Abbadia at a mean epoch about 1903, and was published in 1915. The Paris Observatory has also completed but not yet published a catalogue of this zone. For the Bordeaux and Toulouse zones, extending from +17° to +4°, revision of the positions of the reference stars is in progress, but no catalogue has as yet been published. Two more catalogues of the Abbadia Observatory from observations made between 1906 and 1916 carry the observations of reference stars down to declination −9°. In the Southern Hemisphere the catalogues of the *Astronomische Gesellschaft* and three catalogues of Cordoba extend as far as −37°. Perth overlaps and extends from −32° to −40°. The zone −40° to −52° is one of the best observed zones in the whole sky. The Cape Catalogue recently published gives positions of over 20,000 stars derived from meridian and photographic observations. It contains all the stars used as reference stars on the photographic plates, and all stars brighter than $9^{m}\cdot0$. The Sydney Observatory has published the reference stars extending from −51° to −55°. The Observatory of La Plata for a somewhat later epoch extends from −52° to −57°. Beyond this limit of south declination nothing has been published recently, but the Melbourne Observatory has observed and formed a MSS. Catalogue extending from −65° to the South Pole.

Re-reduction of Old Catalogues. — In 1919 Professor Hepperger, Director of the University Observatory of Vienna, published a new edition of *Argelander's Zone Observations* from 45° N. to the North Pole. This revision of Oeltzen's Catalogue was prepared by Professor Weiss, who corrected a large number of errors which had been discovered, and also employed the improved tables of reduction given by Argelander for 49 of the zones. The positions are given for 1842·0.

Dr. Schorr, Director of the Hamburg Observatory, has completely re-reduced the observations made by Rümker at Hamburg between the years 1836 and 1856 (for which Rümker received the Gold Medal of the Society in 1854). The catalogue, which contains 17,724 stars, is reduced to Auwers's system, and gives the positions of the stars for 1845·0. The catalogue appears to be satisfactorily free from systematic error, and the accidental error of a star place is about $\pm 1''\cdot0$. A comparison is made with the catalogues of the *Astronomische Gesellschaft*. This catalogue should be of real value in the determination of the proper motions of many stars between magnitudes $8^m\cdot0$ and $9^m\cdot0$.

A catalogue of the declinations of stars from $-30°$ to the South Pole has been formed by Baron de Vos van Steenwijk from observations made at Paramatta in the years 1823–28. The original observations were obtained from manuscripts, some in the possession of the Royal Society and others in that of the Observatory of Hamburg. The catalogue contains 2840 stars, the number of observations for each star varying from 20 to 2 or 3. It will be of considerable value in the determination of proper motions of faint Southern stars, a task on which Dr. Van Steenwijk is engaged.

Geschichte des Fixsternhimmels.—The volumes for 0^h and 1^h for the Northern Hemisphere of this great work have been published. They give in a collected form the results of meridian observations from 1750–1900 for all stars north of the Equator, brought up on a uniform system to the epoch 1875·0. Precessions and secular variations are also given for each star which will facilitate comparison with observations made since 1900. This project owed its inception to Dr. Auwers, and is largely indebted to the enthusiasm and industry of Dr. Ristenpart. Each volume, as it is published, will be a great boon to astronomers interested in Meridian Astronomy. F. W. D.

The Plan of Selected Areas.

The total number of stars brighter than 15^m is estimated at 15 millions. Knowledge of these and even fainter stars is destined to play a great part in elucidating the structure of the stellar system; but it is clear that even with the widest co-operation it will only be possible to deal with samples of this great multitude. With a view to organising the study of samples in the best possible way, Kapteyn, after consulting other astronomers, put forward his Plan of Selected Areas in 1906. He chose 206 areas distributed uniformly over the sky, and proposed to secure for these areas catalogues of proper motions, magnitudes, colour indices, radial velocities, etc., pushed in each case to the extreme limit

of faintness attainable. In addition, 46 special areas were chosen to provide for the study of abnormal kinds of stellar background (dark rifts and rich star-clouds), which, though untypical of the general distribution, are none the less deserving of investigation. Unlike such a scheme as the Astrographic Catalogue, which involves co-operation between those engaged in the same branch of astronomy, the "Plan" organises co-operation between the most diverse branches; without this link there would be great dispersal of data for the faint stars, proper motions being measured for one selection, colour indices for a different selection, and so on.

Professor van Rhijn, on whom as successor to Kapteyn at the Groningen Astronomical Laboratory the responsibility for pressing on the completion of the scheme has fallen, has recently issued the Third Report (*Hoitsema Bros., Groningen*). Great progress has been made with the first essential—a comprehensive survey giving approximate positions and magnitudes of all the stars in the areas. The work, which is due to the labours of Harvard and Mount Wilson Observatories and the Groningen Laboratory, is now nearly ready for the printer. It will include stars down to average limiting magnitude about 16·0 for all areas, supplemented for the central part of each area ($15' \times 15'$) in the northern heavens by the inclusion of all stars to a limit between 18^m and 19^m. With this great reference catalogue it will be possible for everyone working on these areas to make clear the identity of the stars he is observing. The state of other portions of the programme cannot profitably be summarised, but we may glance at a few points. As regards proper motions, the earliest comprehensive results would seem likely to come from the Radcliffe and Cape Observatories, which have the great advantage of an early start (1907–9). For colour indices the most advanced work appears to be that of J. A. Parkhurst on the areas in Dec. $+45°$; the limiting magnitude is between 14·0 and 14·5. More extensive investigations are in progress by F. H. Seares, who has been one of the leading co-operators in the Plan; his report on the magnitude investigations is printed in the Appendix. It is interesting to learn that the classification of stellar spectra in the Selected Areas is being extended from $8^m·5$ (the limit of the Draper Catalogue) to 12^m; as far as 11^m the work is being undertaken at Hamburg, but as usual the faintest stars have to be left to Mount Wilson. Whilst a considerable programme is now provided for, it is clear that there is still room for anyone wishing to undertake systematic work on faint stars to contribute to the Plan; those engaged in more desultory work of an experimental character can profit from the Plan, since by working on Kapteyn areas they will be observing objects whose principal characteristics have been, or shortly will be, determined.

Van Rhijn adds some brief remarks on the direction of future investigations, including a good word for the most criticised part of the scheme—that of bulk determinations of parallaxes. Everyone nowadays understands that this is not a thing to be undertaken light-heartedly, and the cautious estimate here given of what results might be obtained with sufficient care will be read with attention. A. S. H.

The Astronomical Tests of Einstein's Law.

There has been a considerable increase during 1923 in the amount of evidence available in favour of the truth of two of Einstein's tests—the gravitational bending of light and the alteration of wave-length in a gravitational field. The evidence in the first of these was derived from discussion of the photographs obtained in Australia of the eclipse of 1922 September 21.

The determination to which most weight attaches was made by the Lick Observatory Expedition to Wallal under Professor W. W. Campbell; the results are published in *L.O. Bulletin*, No. 346.

There are two features which give this determination more weight than those of 1919 May: (1) the distorting effect of mirrors in the optical train was not present, the camera, which was of 15-feet focus, with 5-inch doublet objectives, being mounted equationally; (2) a check field of the same declination as the eclipse field, but distant 6^h in R.A., was photographed on the eclipse plates and also on the control plates of the eclipse field at Tahiti. The telescope and plate remained unmoved between the exposures on the eclipse and check field; one exposure on the latter was made on the night before the eclipse, the other on the night following. A further difference in the conditions from those of 1919 was the much larger number of stars photographed. This is the result of the longer exposures necessitated by the greater faintness of the stars in the eclipse region in 1922. The larger number gives a fuller determination of the manner in which the deflection changes at different distances from the Sun, but the longer exposure increases the chance of distortion of images arising from errors of driving. But careful guiding minimised this source of error.

After the 1919 results were announced, many suggestions were made as to possible causes, other than Einstein's law, that might explain all or part of the observed shift. These are all collected in the *L.O. Bulletin*, and their effects discussed. It is noted that the effect on the film detected by Ross, of more rapid drying of the blackened portion of the plate, would have the tendency to make the measured light deflections too small.

As an illustration of the care with which the measures were discussed, it is stated that they are corrected for the effects of proper motion, annual parallax, differential refraction and aberration, and tilt of plate. β Virginis has a measured parallax; for three other stars parallaxes were assumed from their proper motions and spectral types.

The zero point, orientation, and scale of the eclipse plates were obtained by using the stars distant more than 2° from the Sun's centre. This was done to avoid assuming the law of shift in advance. Once the measures indicated a law closely agreeing with that of Einstein, the scale could be recalculated by allowing for the effect of the shift on the outer stars.

The resulting shift at the Sun's limb from Campbell's measures of three plates is $1''{\cdot}60 \pm ''{\cdot}14$, and from Trumpler's measures of four plates $1''{\cdot}78 \pm ''{\cdot}11$. The adopted value is $1''{\cdot}72 \pm 0''{\cdot}11$, Einstein's predicted

value being 1″·745. The equatorial quadrants gave 1″·63 ± ″·15, the polar ones 1″·76 ± 0″·18; the difference is considered to be accidental.

It is found that if corrections derived from the check field are applied, the radial shift is increased to 2″·05 at the limb. But the propriety of applying them is held to be doubtful, owing to the different conditions under which the check exposures were made. It is preferable to make them during totality where possible, but it was considered impracticable in this case. The plates of the 5-feet cameras, with a larger field, are expected to give additional information as to the shift in the outer regions; it is conjectured that it may be due to Courvoisier's "annual refraction."

The Canadian Eclipse Expedition under Dr. C. A. Chant also observed at Wallal. Their camera had a doublet lens of 6 inches aperture and 11 feet focal length. They availed themselves of Dr. Trumpler's offer to take check plates at Tahiti at the same time as his own, an arrangement being provided to enable their camera to be carried on the Lick mounting.

A preliminary discussion of the results by Dr. R. K. Young appeared in the *Journal of the Royal Astr. Soc. of Canada*, **17**, No. 4. Both the Lick Observatory and Canadian party made use of a key-plate exposed with the film away from the object-glass, which was then placed in succession in contact, film to film, with the check and eclipse plates.

Differential refraction and aberration were first applied, and the plate constants were then found by equations that included the first-order terms in x and y; the Lick investigation included some second-order terms. Nineteen star images were available, but one was immediately rejected. The solution with the remaining 18 stars gave for the Einstein shift at the limb the values 1″·38 and 2″·09 from the two eclipse plates. Other solutions were made, leaving out certain stars that were considered unsatisfactory; they indicated the values 1″·30, 2″·17, 1″·73, 2″·75.

The mean of the six is 1″·90, the probable error is somewhat over ± 0″·2.

The third Einstein investigation in the 1922 eclipse was made by Mr. G. F. Dodwell, Director of the Adelaide Observatory, at Cordillo Downs. The results are described at length in *M.N.*, **84**, 150, so a brief summary suffices here. The camera had a doublet lens, 4 inches in aperture, 64 inches focus, lent by Professor H. D. Curtis, the mounting being lent by Professor Campbell. This investigation has one point of notable superiority over the two previous ones; a check field was taken on the plates during totality, the conditions as to focus and refraction being thus identical with those on the eclipse field. In this way the whole of the Einstein shift on the plates can be utilised; in other cases, since both scale and shift have to be determined from the eclipse plates, only a portion of the latter can be utilised. The camera was bolted so as to have no movement in declination; stops were provided in R.A. so as to enable it to be moved rapidly through 6° in R.A. and back again.

This method of taking check plates has the further advantage that it tends to eliminate abnormalities of refraction due to the fall of temperature within the shadow. Some people have gone so far as to ascribe the whole observed shift to this cause: but while conceding that some deflection of light is not improbable, it is scarcely conceivable that it

could produce a radial displacement following the law of inverse distance from the apparent centre of the Sun at all points within the shadow track.

It was found that only the two plates that had images of the check field upon them could be utilised in the discussion. The four values for the shift at the Sun's limb, given by the measures in x and y on the two plates, are x_1 2″·31, x_2 1″·64, y_1 2″·40, y_2 0″·71; mean 1″·77. The probable error is about ±0″·3.

It will be seen that all three results, viz. 1″·72 ± 0″·11, 1″·90 ± 0″·2, 1″·67 ± 0″·3, differ from Einstein's predicted value 1″·75 by less than their estimated probable errors; the 1922 eclipse has therefore very greatly strengthened the observational evidence for the existence of the shift. On the other hand, J. Hopmann (*Phys. Zeit.*, 24, 476) and E. Esclangon (*C.R.*, 178, 196) have discussed the observed deflections with special reference to the variation of deflection with distance from the sun and the possibility of Courvoisier refraction, and both writers conclude that the observations are insufficient to furnish a decisive confirmation of the Einstein theory.

The third Einstein test, the gravitational shift of the solar spectral lines, has received a notable accession of support in Dr. C. E. St. John's paper (*M.N.*, 84, 93). The chief cause of his change of attitude was his recognition of the very small pressure in the reversing layer, so that it was no longer necessary to confine the study to lines which are insensible to pressure shift.

The study of some 350 iron lines in the centre of the Sun's disc, and comparison with those of the iron arc, both *in vacuo* and at atmospheric pressure, gave results that were explicable on the hypothesis that the Einstein shift exists and that superposed upon it are Doppler displacements indicating downward velocities of 0·3 km./sec. at the upper layers of the solar atmosphere, and upward ones of 0·2 km./sec. at the lower layers. But if a shift only half that of Einstein was postulated, there would be downward velocities in all the layers, varying from 0·6 to 0·1 km./sec.

The results of comparisons made near the limb of the Sun indicate a shift in excess of the Einstein value; differential scattering in the long paths that the rays traverse through the solar atmosphere is suggested to explain the excess.

Mr. Evershed noted that his results were in full accord with those of Dr. St. John. The measures of the solar spectral lines no longer offer any difficulty to the existence of the Einstein shift, even to those who hesitate about adopting this explanation of the observed facts.

Professor H. A. Lorentz, in his address to the Society at the June meeting, described a fourth astronomical effect of Einstein's Law: this was suggested by Schouten, Fokker, and Kramer, and is a small additional precession, whose amount is 1″·9 per century, which is 1/2600 of the ordinary precession. But the new term, unlike the other, would be present even if the Earth were a perfect sphere. The manner in which it arises is briefly indicated on p. 212 of the *Observatory*. Professor Eddington noted that its existence was foreshadowed in Professor de Sitter's papers to the Society in 1917, though its nature was not then

realised. Its numerical value is just half the Einstein secular shift of the Earth's perihelion.

At present the amount of the precession is determined by observation rather than by theory; the shape and internal constitution of the Earth are not known with sufficient accuracy to make the new term available as a test at present, though it might conceivably become one in the future. A. C. D. C.

Photo-electric Photometry.

Photo-electric methods of photometry are now becoming so much a routine matter in some observatroies that a short description may be desirable. When light of certain wave-lengths falls on a metal, electrons are emitted. Certain metals, notably the alkali metals, emit a comparatively large number of electrons, *i.e.* a comparatively large current is produced for unit energy of incident light. The sensitivity of these metals defined as the ratio of current to light varies with the wave-length, the maximum being at about 5500 for cæsium, 4850 for rubidium, 4400 for potassium, and 3400 for sodium. A so-called photo-electric cell consists usually of an evacuated glass vessel containing a grid, the walls being covered except for one part, where the light can enter, with colloidal metal. If such a cell is placed at or behind the focus of a telescope, the light from the star falling on the metal causes the emission of electrons which can be caught on the grid. The rate of rise of potential of the grid is a measure of the number of electrons produced per second, and therefore of the intensity of the incident light. The effect can be amplified by introducing into the vessel an inert gas at low pressure and accelerating the electrons so that they ionise by collision. In general, in astronomical work the currents are too small to be measured by means of a galvanometer, and the much more sensitive expedient of measuring the rate of increase of the potential of the grid is used. For this purpose an electrometer is connected to the grid, adequate precautions being taken to prevent any variation of capacity of the system photo-electric cell-electrometer when the telescope is moved. If the capacity is constant the rate of increase of potential is directly proportional to the intensity of the incident light. Attempts have been made to amplify the photo-electric currents by means of wireless valves, but as the circuits used involve the substitution of a galvanometer for the much more sensitive electrometer they scarcely represent any material improvement.

Photo-electric photometry can be used for any star which is easily visible to the eye through the telescope available, *e.g.* 10th magnitude stars can be measured with a six-inch objective. It is extremely accurate, a difference of 0·002 of a magnitude being detectable when measuring the brighter stars. It can be applied equally well to point images such as stars or extended images such as comets or nebulæ. By a suitable choice of metal and the use of two cells the equivalent of a large colour index can be obtained.

This method has been applied successfully at the Babelsberg Observatory. Improved methods have been worked out at Sidmouth

(*M.N. of R.A.S.*, 1919 March), and attempts have been made this year at the Lick Observatory (*Lick Observatory Bulletin*, 349). It is to be hoped that it will be applied on a large scale at some English observatory before long.

For many purposes the indirect method of photographing the celestial object or its spectrum and measuring the blackening photo-electrically has proved useful. Introduced originally some ten years ago by P. P. Koch this method has been applied successfully to stellar spectra by R. A. Sampson (*M.N.*, **83**, 3), and a very accurate type of instrument enabling measurements to be made with a probable error of 0·1 per cent. has been designed by G. M. B. Dobson (*Proc. Roy. Soc.*, A. **104**, 248).

F. A. L.

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ADDRESS

Delivered by the President, Dr. J. L. E. Dreyer, on the Desirability of Publishing a New Edition of Isaac Newton's Collected Works.

Of late years a strong desire has been felt everywhere to have the collected works of great scientific leaders published in standard editions. Confining ourselves to astronomers and mathematicians and to the period from about 1500 to 1800, we find that fine editions have been published within the last sixty years of the works of Copernicus, Tycho Brahe, Kepler, Galileo, Torricelli, Descartes, Fermat, Huygens, Leibniz, Euler, Lagrange, Laplace, William Herschel, and perhaps one or two more. But the greatest name of all is missing from the list, that of Isaac Newton.

In three years' time 200 years will have elapsed since the death of Newton and during that time only two editions of his collected works have been issued. The first one was edited by an Italian named Castiglione, but whether it includes all the writings published by Newton, I am unable to say. There are three volumes of *Opuscula Mathematica, Philosophica et Philologica* (Lausanne, 1744), and the *Arithmetica Universalis* in two volumes (Amsterdam, 1761); but I cannot find any sign of the *Principia* and the *Optics* having been reprinted by Castiglione. The only edition of Newton's Opera Omnia approaching completeness was edited by Samuel Horsley, and was published in 1779–1785, in five quarto volumes. But this edition is very far from fulfilling modern requirements. Very little use was made by Horsley of unpublished material, while there is an entire absence of introductions and notes. Not a word is said as to when and under what conditions the various books and papers were originally issued, nor are there any lists of variants of the different editions published during the lifetime of Newton. The poverty and insufficiency of this old edition become very glaring, when one compares it with any of the standard editions alluded to above, such as the magnificent *Œuvres complètes de Christiaan Huygens*. On the other hand, it must in fairness to Horsley be conceded that his work is not worse than, for instance, Albèri's edition of Galileo, which is now quite superseded by the Edizione Nazionale of Favaro.

Let us glance at the material which would be at the disposal of prospective editors. G. J. Gray's "Bibliography of the works of Sir Isaac Newton" (Cambridge, 1907), though not without faults, is very useful; but of much greater importance is the "Catalogue of the Portsmouth Collection of Books and Papers written by, or belonging to, Sir Isaac Newton," Cambridge, 1888, 86 pp. These papers came, on the death of Newton, into the possession of Mr. Conduitt, who had married

Newton's favourite niece, Catherine Barton. By the marriage of their only child to the first Lord Lymington, the papers passed into the hands of the family of the Earl of Portsmouth, where they remained until all that portion which related to science was presented by Lord Portsmouth to the Cambridge University Library. All the papers on Theology, Chronology, and Alchemy were returned to Hurstbourne Park, Hants, where they are being preserved. Before being divided, the whole collection was examined at Cambridge by a committee consisting of H. R. Luard, G. G. Stokes. J. C. Adams, and G. D. Liveing, whose most valuable and lengthy report and catalogue are dated 1888 May 26. With the exception of some letters printed in Brewster's biography of Newton, no use has hitherto been made of these papers, and nothing else has been printed except a few exceedingly interesting details included by the committee in their report, to which I shall presently refer. Apparently there is nothing else of much importance among the mathematical papers, except some points of purely historical interest.

In addition to the letters in the Portsmouth Collection there are many letters preserved in other places, at Trinity College, Cambridge (correspondence with Cotes), in the Macclesfield Collection (where there are also other papers which have never been examined), at Corpus Christi College, Oxford, and elsewhere. Most of these have been printed, but a chronologically arranged catalogue of them should be formed, in order to decide how many of them should be incorporated in a new edition of Newton's works.

The scientific writings of Newton may be divided into those on Optics, the *Principia*, and papers and books on pure Mathematics. I leave aside the theological and chronological papers, which it would perhaps hardly be worth while to print again. The works on Optics consist of papers published in the *Philosophical Transactions* (6–11, 1672–1675); the great work on *Opticks* published in 1704; and the "*Optical Lectures*, read in the Publick Schools of the University of Cambridge, A.D. 1669" (London, 1728). All these should be published exactly as they were first sent to the Royal Society or printed, and should be illustrated by whatever letters may be found bearing on this subject. The treatise on Optics was kept back from publication for many years until after the death of Hooke, owing to Newton's excessive dislike of polemics, which made him discontinue his communications to the Royal Society from 1676. It will therefore be of special interest to have every line, written by Newton on Optics, reprinted in chronological order.

If we now turn to the *Principia*, the case is more complicated. You will remember that three editions were published during the lifetime of Newton, the first in 1687, seen through the press and printed at the expense of Halley; the second edited by Cotes in 1713; and the third by Pemberton in 1726. All the circumstances of the publication of the first edition have been carefully described in two monographs by Rigaud (*Historical Essay on the First Publication of Sir I. Newton's 'Principia,'* Oxford, 1838), and W. W. Rouse Ball (*An Essay on Newton's 'Principia,'* London: Macmillan, 1893). As to the preparation of the second edition

we have the *Correspondence of Sir I. Newton and Professor Cotes*, edited by J. Edleston (London, 1850), which book also contains letters from other eminent men, from the originals belonging to Trinity College, Cambridge. We are less well informed about the third edition, but the Portsmouth Collection contains twenty-three letters from Pemberton to Newton and seven sheets of queries by Pemberton. The second edition was reprinted at Amsterdam in 1714 and in 1723. The third edition has often been reprinted, with or without commentaries, the best known being that of Le Seur and Jacquier, three (really four) volumes, Geneva, 1739–42, and again in 1760.

Among the Portsmouth papers there are several in which subjects dealt with in the *Principia* are discussed more fully. There is thus an investigation of the motion of the lunar apogee, made apparently in 1686. There is also a detailed calculation of the refraction at the altitudes 0°, 3°, 12°, and 30°. The papers show that the well-known approximate formula for refraction, generally known as Bradley's, was really due to Newton. The formula is only applicable when the object is not very near the horizon, but the method of calculation employed by Newton is equally valid, whatever be the apparent zenith distance.

Finally, the papers contain a long list of propositions in the Lunar Theory, which were evidently intended to be inserted in a second edition of the *Principia*, which Newton thought of bringing out in 1694. It has been printed both by the Committee and in Mr. Rouse Ball's *Essay*.

All these addenda to the *Principia* date from before the year 1696. In that year, to the great detriment of science, Newton accepted the office of Warden of the Mint, and three years later he was promoted to the office of Master, which he held for the remainder of his life. The adulterated coinage of the country had to be restored, the five country mints had to be abolished, and the work at the Tower to be reorganised. This was done in the course of a few years, and even if we grant (what few would be disposed to do) that this work of reform could only be done by a man of most unusual ability, it is at any rate utterly deplorable that the transcendent genius of Newton should for many years afterwards be wasted on office work, which hundreds of people could have done equally (or at least sufficiently) well. Newton was a most conscientious man, and worked hard to earn his fine salary. The "Eighth Report of the Royal Commission on Historical Manuscripts" (London, 1881, fol.) gives a lengthy account of the contents of three large folio volumes of Mint papers in the Portsmouth Collection. It is very sad to read of the immense amount of work Newton did at the Mint; of how much time he had to spend on letter-writing, hardly ever being able to write an official letter to his own satisfaction without first writing several drafts; and how he had to see to the detection and prosecution of coiners and clippers.

It is no wonder that Newton, when at last the preparation of a second edition of the *Principia* had to be undertaken, handed it over to Cotes. Thanks to the correspondence between him and Newton, published by Edleston, we know a great deal about how this edition

was produced. Newton's manuscript corrections of it, used for the third edition, are in the Portsmouth Collection.

Mr. Rouse Ball wrote in 1893 (*Essay*, p. 74): "A complete edition of the *Principia* should, I think, show the changes made in the second edition, and the further changes introduced in the third edition. I possess in manuscript a list of the additions and variations made in the second edition; the changes are very numerous, in fact I find that of the 494 (*i.e.* 510–16) pages in the first edition, 397 are more or less modified in the second edition. The most important alterations are the new preface by Cotes; the propositions on the resistance of fluids, book ii., section vii., props. 34–40; the lunar theory in book iii.; the proposition on the precession of the equinoxes, book iii., prop. 39; and the propositions on the theory of comets, book iii., props. 41, 42. I have not formed a list of the changes introduced into the third edition, but I believe that the bulk of them are given in the list by Adams, which is printed by Brewster; * the most important being the scholium on fluxions, book ii., lemma 2, and the addition of a new scholium on the motion of the moon's nodes, book iii., prop. 33, to which I may add an account of some additional experiments on the resistance of the air to bodies falling through it, and the use of some fresh astronomical observations in book iii."

All these variants are of great importance, and should be clearly indicated in any critical edition of the *Principia*. Perhaps the proper thing to do would be to reprint the first edition on the right-hand pages of the open book, giving the alterations and additions on the left-hand pages.

In connection with the *Principia* I may mention the tract "Propositiones de motu" (printed both by Rigaud and by Ball), which contains the chief propositions given by Newton in his lectures in 1684. Also the little book *De mundi systemate*, a short, popular account first printed in 1728, again issued in 1731.

We come next to Newton's publications on Algebra and Fluxions, and they are, unfortunately, not numerous. They are all contained in Horsley's first volume. In 1704 Newton appended to his *Optics* two papers written many years earlier, one on cubic curves, the other on the quadrature of curves and on fluxions. In 1707 his *Arithmetica Universalis* appeared, and in 1712 his paper "De analysi per equationes numero terminorum infinitas," written in 1669, but the results of which had been found as early as 1665–66, was at last given to the world. The substance of it had, however, been printed in the second paper issued in 1704. The *Method of Fluxions*, written about the same time, was at last translated into English and published by Colson in 1736. The original was printed by Horsley with the title *Geometria Analytica*.

Finally, no edition of Newton's works would be complete which did not include the celebrated book, *Commercium Epistolicum*, of which Newton quite certainly wrote the "Account" in the *Phil. Trans.* for 1715, and for which he supplied all the materials. Therefore he was

* Brewster (1855), 2, 304–309, 414–419.

responsible for this book, which was nominally the work of a committee appointed in 1712, not to judge impartially whether Newton or Leibniz was the first inventor of the fluxional calculus, but to state Newton's case. To make this book intelligible to the majority of readers of the proposed edition (who cannot be expected to have studied the History of Mathematics in the seventeenth century), there ought to be added an Introduction showing the gradual growth of the integral and differential calculus. The integral calculus can really be traced back to the Greeks, who by the "method of exhaustion" of Eudoxus and Archimedes were able to solve various problems of quadrature and cubature. In the first half of the seventeenth century this was taken up by Cavalieri, whose principle of indivisibles was a distinct improvement on the Greek methods. He was followed in rapid succession by Fermat, Pascal, and Wallis. With regard to differentiation the case is different; Fermat was the first to determine maxima and minima and draw tangents, and these problems were also studied by Hudde, Sluse, and Barrow. But none of these precursors produced general rules, and none of them had realised that the drawing of tangents and the quadrature of curves are inverse operations. These were the great discoveries of Newton, and are found in his paper "De analysi per equationes, etc.," already mentioned.

The question whether Leibniz, independently of Newton, discovered the differential calculus by building on the foundations laid by the precursors I have mentioned, or whether he got the idea from Newton in some way or other, has been debated from time to time during more than two hundred years. But the discussion of it cannot be shirked by an editor of Newton's works, as it would be most improper to re-issue the *Commercium Epistolicum* without a commentary. This is not the place to give an account of the controversy, but I should like to point out that the alleged proofs of the supposed plagiarism of Leibniz have undergone a remarkable change since the *Commercium Epistolicum* first appeared.

In that work it is stated that Leibniz did not possess any Differential Method before his letter of 1677 June 21, which was a year after a copy of Newton's letter to Collins of 1672 December 10 had been sent to Paris to be communicated to Leibniz. Furthermore, that there was among the papers of Collins belonging to the Royal Society a bundle containing extracts from Gregory's letters, and also the letter from Newton, marked as to be sent to Leibniz by Oldenburg. Now it appears from an examination of the papers of Leibniz in the Library at Hanover (the results of which were first published in 1849) that in them *as in Collins' draft* (at the Royal Society) there is only an abstract of Newton's letter, omitting the example of drawing a tangent to a curve, and merely alluding to the method.* And anyone who reads the letter in the Macclesfield Correspondence (2, 338) and compares it with Sluse's

* Edleston, xlvii. Compare De Morgan's paper "A Short Account of some Recent Discoveries relative to the Controversy on the Invention of Fluxions," in the *Companion to the Almanac for* 1852, reprinted in *Essays on the Life and Work of Newton*, by Augustus de Morgan, edited by P. Jourdain (Chicago and London, 1914, Open Court Publishing Company). De Morgan's paper was unknown to every continental historian of Mathematics—Cantor, Enestrom, Zeuthen.

paper in the *Phil. Trans.*, No. 90 (1672), will acknowledge, that even if Leibniz had got the whole letter, it would not have taught him anything which he might not just as well have learned from Sluse's paper.

But if we turn to the Catalogue of the Portsmouth Collection (p. xvi), the charge against Leibniz is a different one. "It is clear from these Portsmouth papers that Newton believed that Leibniz, during his second visit to England in 1676 October, had obtained access to his MS. entitled 'De analysi per equationes numero terminorum infinitas,' which was in the hands of Collins, and that he had thus been materially assisted in discovering the Differential Calculus. This tract of Newton's is printed in full in the *Commercium Epistolicum*, and is there used merely in order to prove Newton's priority to Leibniz. It is nowhere asserted or even implied in the *Commercium* that this tract of Newton's had ever been seen by Leibniz. There can now be no doubt, however, that Newton was right in thinking that Leibniz had been shown this MS., since a copy of part of it, in Leibniz's hand, has been found among the papers of Leibniz preserved in the Royal Library at Hanover."*

The existence of this MS. copy is certainly strange, but as it bears no date and Newton's paper was not printed till 1712, it is, of course, quite possible that Leibniz made that copy after 1675 November, at which time the papers at Hanover show that he was in possession of the fundamental principles of the Calculus. But the Portsmouth papers ought to be examined very thoroughly to find *why* Newton thought that Leibniz had got hold of the paper "De Analysi" in 1676 October. If the date of 1675 November 11 is certain, when Leibniz (mentioning Sluse's name) worked out problems by means of his new Calculus, it cannot have helped him much in the discovery of it to have obtained access to Newton's paper nearly a year later.

With regard to the very numerous letters written by Newton or to him, there are two ways of making use of them. Most editors print such letters in chronological order without omitting any of them. This plan has the drawback, that many uninteresting details and repetitions are included, which sometimes makes the reading of a bulky collection of letters rather tedious. This is avoided if the plan adopted by Frisch in his excellent edition of Kepler's works be followed. He only supplies copious extracts from the letters in the lengthy introductions which he gives to each of Kepler's writings. An eventual editor of Newton's works will have to consider very seriously the relative merits of these two methods.

I feel sure that the Fellows of the Royal Astronomical Society will not think it inappropriate, that I have chosen this occasion to call attention to a most deplorable gap in the scientific literature of this country. Whose portrait hangs over your President's chair?—Newton's. Whose image adorns the Gold Medal, the greatest mark of your appreciation which you can give to an astronomer?—Newton's. As a Society we

* Gerhardt, *Mathem.-Schriften Leibnizens*, 1, 7. *Cf.* H. Sloman, "The Claim of Leibniz to the Invention of the Differential Calculus," Cambridge, 1860, p. 65.

are, of course, quite unable to undertake any pecuniary responsibility in addition to that connected with our regular work. But we have in our midst a number of distinguished members of Newton's old University, who doubtless feel, even more than other astronomers and mathematicians do, the want of respect to the memory of Isaac Newton implied in the neglect to publish a proper edition of his works. To them I address an earnest appeal to put an end to this state of things. Surely the pecuniary means will be forthcoming, if the proper amount of talent and enthusiasm can be secured.

Election of Officers and Council.

The Meeting then proceeded to the election of Officers and Council for the ensuing year, when the following Fellows were elected:—

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A. S. Eddington, Esq., M.A., M.Sc., F.R.S., Plumian Professor of Astronomy, Cambridge.
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